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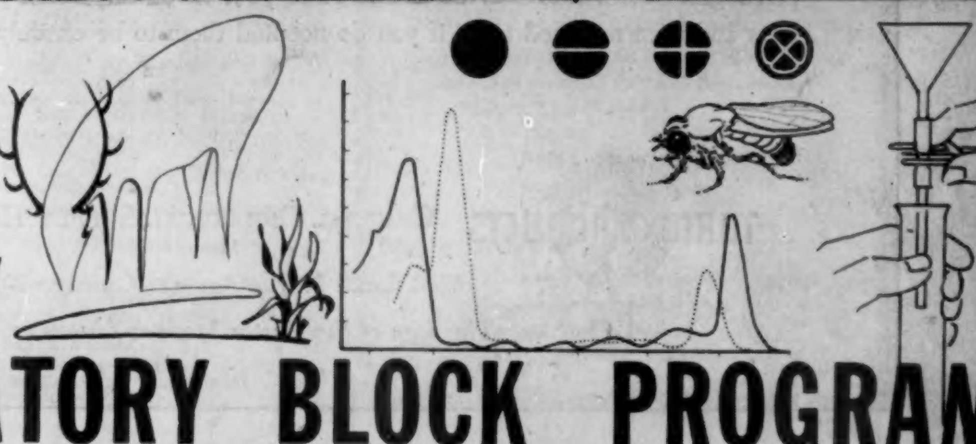

ABORATORY BLOCK PROGRAN

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THE AMERICAN BIOLOGY TEACHER

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The Experimental Approach in Teaching Biology

An Introduction to the BSCS Laboratory Block Program

• *Addison E. Lee,* University of Texas, Austin*

During the past 60-70 years more than 100 committees have made recommendations for the development of science curricula. These have been committees representing major professional groups at the national level. They have included on their personnel distinguished scientists, public school teachers and administrators, and professional educators. It is generally agreed that the recommendations they have made have been worthwhile and timely. Why, then, the current attention to curriculum development in the sciences?

There are two reasons. First, once again current events demand a re-evaluation of what is actually being taught. Science has a different place in all of our lives today compared to what it had 70 years ago—40 years ago—20 years ago. Second, many of the excellent recommendations of past committees somehow have never come into widespread, actual use in many classrooms.

As is well known in professional circles now, once again science curricula are being re-evaluated and new designs are being developed in all of the sciences. The Biological Sciences Curriculum Study, organized under the auspices of the American Institute of Biological Sciences, has undertaken to pool together some of the best biological talent—high school biology teachers and professional biologists from college and research programs—for the purpose of developing new approaches to teaching biology.

As a part of the total BSCS program, the Committee on Innovation in Laboratory Instruction was organized and assigned the task of developing a new approach in laboratory instruction. We have called this new approach "The Laboratory Block." It really means that a biology teacher will divide a year's biology course into two somewhat distinct parts. Thirty weeks of the course will be used to provide a broad coverage of the subject, employing both new and/or classical teaching techniques. Six weeks of the course, the laboratory block, will be used to provide the student with a laboratory approach involving a study in depth of a specific biological topic following the pattern a scientist might employ to investigate the same problem if the scientist were beginning at the same starting place as the student. The student will be required to acquire sufficient background information to investigate the problem at hand. He will learn the necessary techniques to carry out required experiments. He will make observations and obtain data relative to the topic at hand. Moreover, he will be expected to interpret his observations and data and to arrive at conclusions which will not only answer specific questions, but will increase his understanding of the fundamental biological principles which underlie the individual laboratory blocks.

The laboratory blocks are designed to guide the student to make discoveries for himself. Some questions or problems will be posed, but no answers will be given in advance. In the laboratory block, the student is really working with an unknown. In making discoveries for himself, the student may often follow in the footsteps of scientists who have preceeded him. On other occasions, he may follow an entirely new approach. The student should be encouraged to keep constantly in mind the possibility of alternative procedures. He should be on the look-out for new problems, design new experiments to investigate them, and to the extent possible, investigate his own problems.

Such procedure will bring the student to the frontier of science, at least to some extent for a particular subject. He will learn biology as a biologist learns it. The student will learn some facts and some techniques, but what we think is more important, he will gain invaluable practice in working like a scientist.

Editions of the first four laboratory blocks written especially for the teacher were made

*Chairman, Committee on Innovation in Laboratory Instruction, AIBS Biological Sciences Curriculum Study, and Director, Science Education Center, University of Texas. The following papers were presented at the NABT meetings with the AAAS in New York, December, 1960.

FIGURE 1. The Austin staff of the BSCS Committee on Innovation in Laboratory Instruction review recent publications of the Committee. Left to right: Mr. Richard Barthelemy, Project Associate; Mr. Don Borron, Project Associate; Dr. Addison E. Lee, Project Supervisor and Committee Chairman, and Mr. James Dawson, Project Associate.

available in limited quantities during the summer of 1960. These are: (1) *Microbes: Their Growth, Nutrition, and Interaction* by Alfred S. Sussman, University of Michigan; (2) *Animal Growth and Development* by Florence Moog, Washington University; (3) *Plant Growth and Development* by Addison E. Lee and Irwin Spear, The University of Texas; and (4) *Interdependence of Structure and Function—A Study of Motion* by A. Glenn Richards, University of Minnesota. During the spring of 1961, these blocks were tried out in 59 different schools across the nation.

These laboratory blocks have been written by active research scientists; tried out and evaluated by high school biology teachers, the project associates, James Dawson, Richard Barthelemy, and Don Borron (see Figure 1); pretested in part by high school students; and then edited and re-written.

This rather elaborate procedure has been followed in order to provide accurate and up-to-date biology content and to have it developed in such a way as to make its use practical in actual high school classes.

As suggested earlier, two books will be available for each laboratory block: a teacher's edition and a student's edition. The teacher's edition contains all of the materials found in the student's edition, including introductory remarks, lead questions, experimental designs, a day-by-day work schedule, technique instructions, graphs and tables to be filled in by the student after he makes his observations and collects his data, reading references, a glossary, and, sometimes, an appendix. In addition to all of the material in the student's edition, the teacher's edition contains suggestions for procedures, possible difficulties which may be encountered, equipment needs, specific examples of data and other results obtained in the initial tryouts of the materials, and answers to many of the possible questions which may be raised.

In addition to the laboratory blocks already prepared and being tried out, several others are in the process of preparation: *Ecology* by Edwin Phillips, Pomona College; *Animal Behavior* by Harper Follansbee, Phillips Academy; *Regulation in Plants by Hormones* by William Jacobs and C. E. LaMotte, Princeton University; *Genetic Continuity* by Bentley Glass, Johns Hopkins University; and *Physiological Adaptation in Animals* by Earl Segal, Rice University.

So much for what we are doing. One may ask what we hope to accomplish and if we expect the work of our committee to fare any better in actual classroom use than that of our predecessors. We think the answer to the latter question is "yes." First, because with the proper support from the National Science Foundation, we are carrying the work much further than our predecessors in the actual development of curriculum materials. Then, the tryout phase of our program is much more extensive than that of our predecessors. We thus hope to have a much greater backlog of both teachers and students who have actually participated in our program and who can defend or condemn it on the basis of their own experience. We think, also, that teachers, students, and the public in general are much more willing now to accept indicated changes and to provide the necessary equipment and facilities to put a new program into operation. We are sure that the need has never been greater.

But one word of caution: If you are eager, as we hope you are, for new curriculum materials, there is always a tendency to say about materials that are submitted, "I knew that. It was discovered several years ago" or "We always study that topic," etc. This may be true for you, of course, for some or even all of the materials we have developed. We are

submitting only "known biology." We are not presenting new biology in the sense that the discoveries have not yet been made. We are trying to provide up-to-date (the latest findings, modern emphasis) biology. This will be new to some teachers and to most beginning students. But much more than that, we are offering the teacher suggested materials to enable the students not only to learn the science of biology but also to practice the science of biology.

The following presentations by the laboratory block authors themselves will give you an understanding of how we expect to accomplish these objectives.

Microbes: Their Growth, Nutrition, and Interaction

• *Alfred S. Sussman, University of Michigan, Ann Arbor*

"The present period is one of protest against methods and matter; a period of dissatisfaction and retesting the curriculum; a period of the study of the grounds and history of teaching." So reads a report prepared by a committee of the Central Association of Science and Mathematics[1] which made the following recommendations for improved science teaching:

1. More emphasis on "reasoning out" rather than memorization.
2. More attention to developing a "problem-solving attitude" on the part of students.
3. More emphasis on the incompleteness of the subject and glimpses into the great questions yet to be solved by investigators.

There is little with which we can quarrel in these recommendations, even though the report was published as far back as 1910. However, in company with other reports of this kind, accomplishment has lagged behind articulation. This is not to denigrate a statement of intentions in curricular reform and, to prove this, I shall provide one of my own. I will divide the basic elements in the study of science into 3 categories including, the *substantive* (illustrative, in the terminology of Dr. Bentley Glass[2]), *methodological* (investigatory) and *personal*, or innate. In the last category I include such prerequisites of the practitioner of science as integrity, conscientiousness, insight and, perhaps, dedication and curiosity. For the most part, I suspect that several of these personal attributes of the scientist are beyond the reach of the teacher; at the very least, I know of no clear evidence to establish that significant changes in these characteristics can be effected in the classroom alone. Perhaps dedication and curiosity do not belong in this category, but I submit that it is a question whether the successful teacher is as much an incendiary, in the sense of kindling interest, as a continuing source of fuel for a fire already lit. In any case, these personal attributes are not required by scientists alone but by creative people in every field.

Those elements which are most characteristic of the scientist are subsumed under the heading of the *substantive*, or subject matter, and *methodological*, or investigatory. Therefore, it is these toward which we have directed our efforts in the AIBS curriculum study, and so I would like to discuss the Microbiology block within this framework.

The Substantive Elements

First, the substantive: what is the subject matter of this block? It concerns the microbes, those organisms whose external morphology can be discerned *only* through a microscope. As Table 1 shows, the subject is organized around the Protista, which includes the bacteria and blue-green algae in one subgroup, and the rest of the algae, protozoa, and fungi in the other. The tedious, and often futile, exercise of fastening the label, plant or animal, to creatures which were created despite such nomenclatorial indecision is thereby

[1]Galloway, T. W., Chairman. 1910. *School Science and Mathematics* 10: 801-813, cited in Hurd, P. DeH. "Biological Education in the United States." 1960, AIBS, BSCS. Boulder, Colorado.

[2]Glass, B. Preface, *Laboratory Blocks,* written for the Committee on Innovations in Laboratory Teaching, BSCS, AIBS.

Table 1

Outline of the Kingdom Protista

Characteristics	Sub-group of Protista
Immobile cytoplasm; lacking vacuoles and chloroplasts; nucleus consists of several centrally located bodies which stain like DNA; flagellum, when present, has only a single fibril; diamino pimelic acid (DAP) present in cell wall	Bacteria and blue-green algae
Mobile cytoplasm; vacuoles and organized chloroplasts present; one nucleus or, when more than one are present, they are larger than 1 micron in size and all but one disappear during sexual reproduction; flagellum has 11 fibrils; DAP absent.	Protozoa, fungi, algae

avoided. Similarities and differences are developed as far as our current knowledge permits.

But why work with these organisms when it is so much easier to see the larger ones? The great importance of microbes to man and other living beings earns them a place in any biology course. In addition, microbes make remarkably fine laboratory materials because their rapid growth telescopes into a few days—and sometimes hours—the whole life history of the organism. Consequently, the heredity, development, and functioning of microbes can be studied without the delays that the slower growth of larger creatures imposes. Furthermore, millions of microbes can be handled in a small space. Such large numbers contribute statistical rigor to experiments which might otherwise have to be restricted to a few organisms.

On the debit side, it must be admitted that more equipment is needed to work with microbes, and techniques like the maintenance of sterility and the preparation of media must be developed. Also, although it is tempting to use facts learned about microbes to explain processes in a larger organism, say an elephant, still, "The proper study of elephants is elephants," if I may paraphrase Alexander Pope's statement about man. Withal, however, much that is basic to all of biology has derived from the study of microbes, and the exercises in this block have been developed with this in mind.

These creatures are first introduced through their habitat in nature. Diversity in the group comes through as a result of the observation of crude cultures prepared from soil and pond water which have been enriched in various ways. The equipment for these "enrichment cultures" is extremely simple as can be seen in Figure 1, which shows the require-

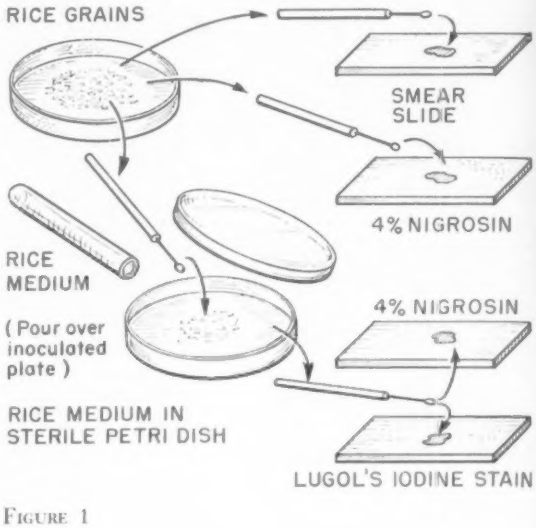


FIGURE 1

ments for an experiment utilizing rice. It can be predicted that a large bacterial rod will be isolated in this case, just as certain fungi and other microbes will be found when another simple enrichment is prepared by the use of cellulose, as is illustrated in Figure 2.

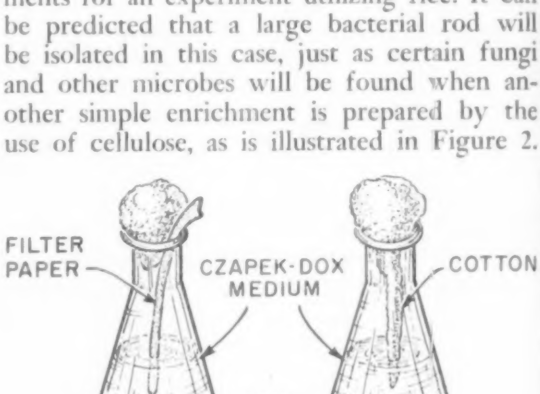


FIGURE 2

Insight into the metabolic versatility and ubiquity of microbes is gained through these and other enrichments performed by different squads. After this, attempts are made to isolate single organisms in pure culture so that a supply of protistans becomes available for demonstration and for use in open-ended experiments.

Then, the growth of a yeast is studied in detail, begun by inoculation from a source

familiar to many students, as can be seen in Figure 3. An example of the kind of directions that are furnished the student is shown in the

FIGURE 3

next Figure 4 in which the details of the procedure are outlined by means of a flow-chart. Environmental factors like temperature are varied, and the data plotted and the curves analyzed.

Having studied the growth of an organism in an undefined medium the student is now asked to consider the exact nature of the nutrient requirements of microbes. A discussion is provided in advance to familiarize him with some of the basic aspects of this subject, some of which are outlined in Table 2. As can be seen, the major chemical requirements are reviewed, as well as their role in cells. Experiments on mineral, carbohydrate, and vitamin requirements are carried out to demonstrate the effect of deprivation and, in some cases, of an excess of these materials.

Table 2

Nutrient Requirements of Microorganisms

Substances	Abbreviation	Number of Organisms Requiring Substance to Be Added
Minerals	—	all
Water	—	all
Gene-Parts	G	some
Protein-Parts	P	some
Vitamins	V	some
Energy-Source (Fuel)	E	many
Oxygen Gas	O	most

But, it is pointed out, organisms rarely, if ever, live in total isolation in nature; entry is thereby gained to the study of interactions. This subject is introduced by way of a study of nitrogen fixation and antibiotic production. For the former, bean plants are grown in sterile and non-sterile soil, as well as in sterile soil inoculated with the nodule symbiont, *Rhizobium*. Growth of the plants over a period of several weeks is used as a measure of the effect of nodulation. As for the study of antibiotics, a crude culture filtrate containing penicillin is prepared and applied to test organisms according to the protocol outlined in Figure 5. It will be noted from this flow chart that the complexity of the experimental procedures grows as the work in the block progresses.

Finally, a two-membered microbial society is reconstructed to indicate how complex associations might be studied experimentally. In this case, the organism that was demon-

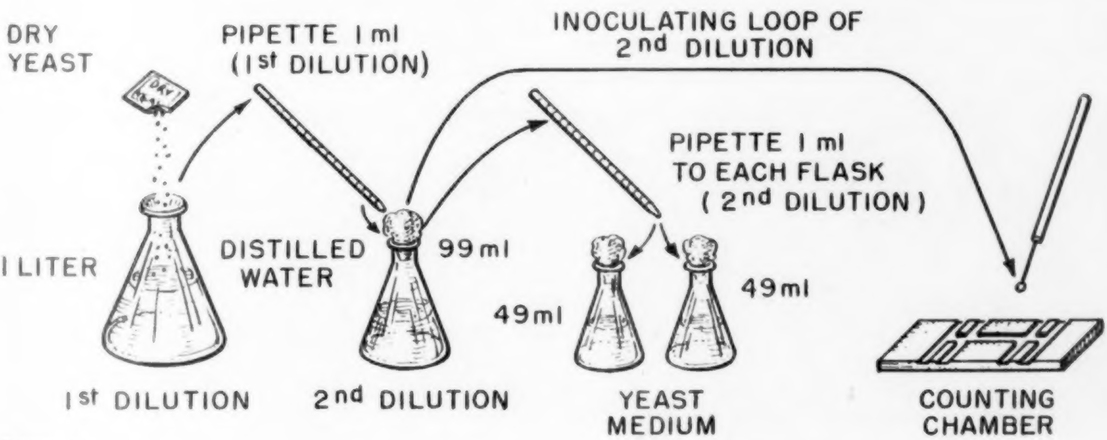


FIGURE 4

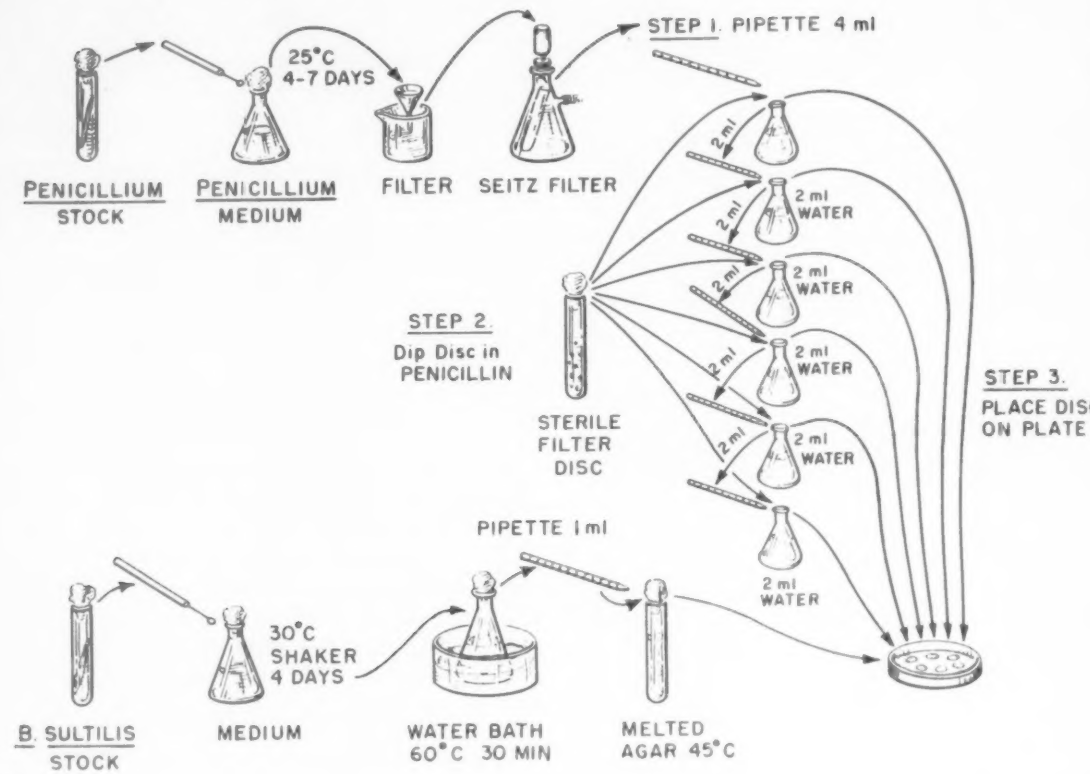


FIGURE 5

strated to require a vitamin in the experiment on nutrition is shown to grow in a medium lacking the vitamin when inoculated together with another fungus. The student can deduce that cross-feeding of this kind may help to explain the survival of organisms that have nutritional deficiencies.

I might note that recognition is made of the difficulty in visualizing bacteria without oil immersion lenses and other equipment that may not be readily available in high schools. For one, the ingenuity of the project associates of this committee has resulted in the design of inexpensive laboratory materials which are effective substitutes for those from commercial sources. Furthermore, microbes are used which can be handled with relative ease "en masse," and whose cells can be readily seen under dry microscope objectives. Thus, such operations as weighing, inoculation, and observation can be performed after only a little experience.

But substantive materials have been presented effectively before. Wherein lies the main difference between the block approach and classical laboratory instruction? I believe the difference to reside mainly in the third category of elements involved in science, namely, the *methodological*: scientific method, if you will. What is involved under this heading?

The Methodological Elements

The need for reliable measurements is made manifest throughout these exercises and basic mathematical techniques are developed as part of data collecting. There are tables like that

NUTRIENT

	Squads	N	Y	C	NY	NC	YC	NYC	CONTROL
EXTENT OF GROWTH	1.								
	2.								
	3.								
	4.								
	5.								
	6.								
	Average (Mean)								

FIGURE 6

shown in Figure 6, dispersed throughout the block, in which the information is recorded. Another type of record is illustrated in Figure

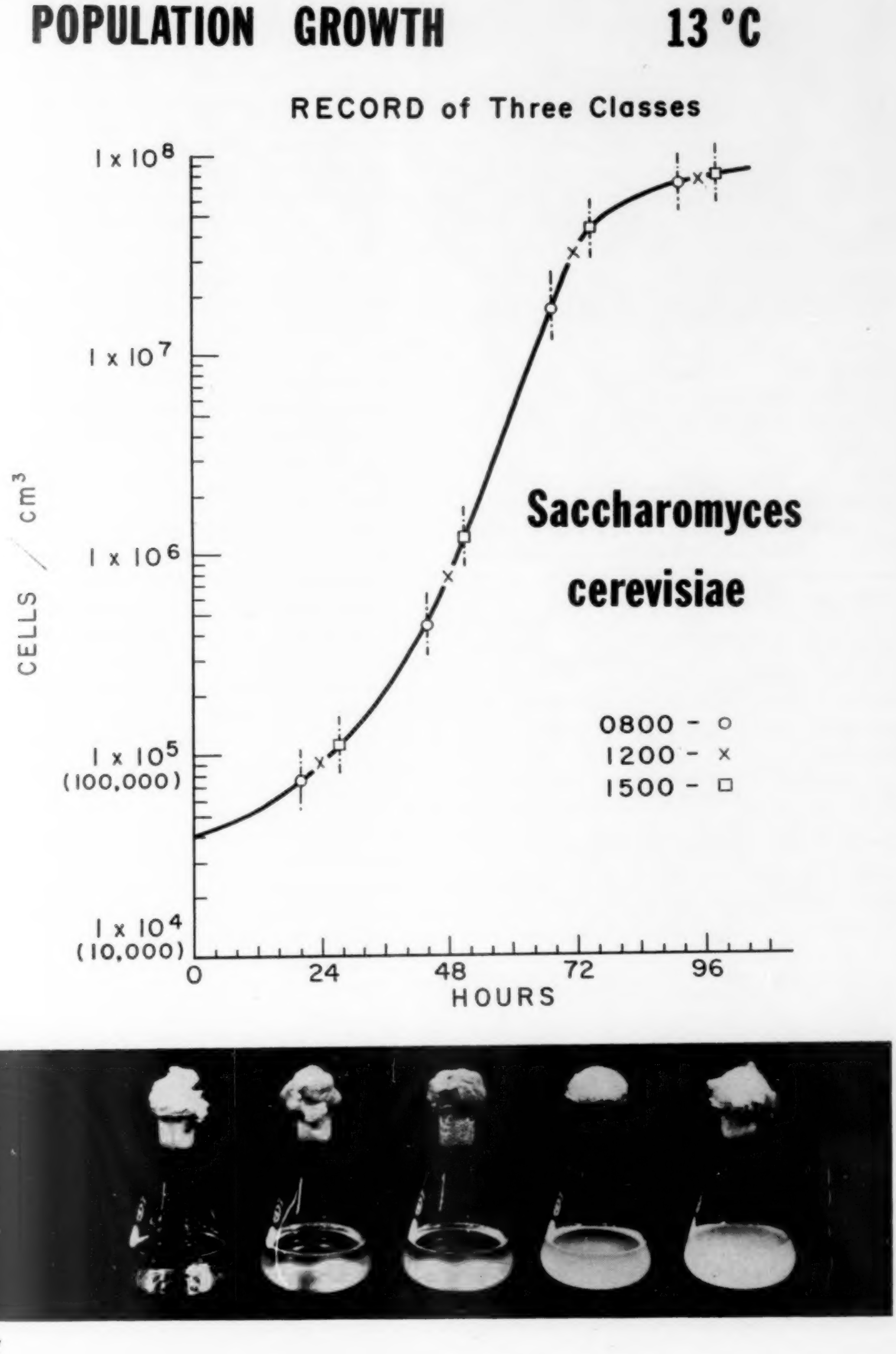

POPULATION GROWTH 13 °C
RECORD of Three Classes
1 x 10^8
1 x 10^7
1 x 10^6
1 x 10^5
(100,000)
1 x 10^4
(10,000)
CELLS / cm^3
0
24
48
72
96
HOURS
Saccharomyces cerevisiae
0800 - o
1200 - x
1500 - □

FIGURE 7

7 which is a curve prepared on semi-logarithmic paper from data obtained during the exercise on growth. Phases in the growth of unicellular organisms are discussed, as well as the reasons for the use of a logarithmic grid instead of an arithmetic one. Moreover, the use of bio-assays, as sensitive and specific analytical tools is stressed in several places.

Analysis and synthesis, as reciprocal yet complementary approaches are both pursued through exercises in this block. Thus, a nutritional deficiency in a mold, *Phycomyces*, is analyzed by means of a sequence of experiments in which the broad class of compounds required is first identified. The materials used in this experiment, as well as the classes of nutrients contained, are outlined in Table 3. Some of the results are illustrated in

Table 3

Substances Used in the "Auxanographic" Study of Nutrient Requirements

Suggested Code Label	Nutrient Solution	Substances Supplied
N	0.5% Yeast Nucleic Acid	Purines, Pyrimidines, etc. (Gene Parts)
Y	0.5% Yeast Extract	Vitamin B Complex, etc.
C	0.5% Casamino Digest, Vitamin-Free	Amino Acids, Peptides (Protein Parts)

Figure 8 which reveals that the deficiency is best met through substances which are furnished in the yeast extract, therefore, vitamins.

FIGURE 8

It should be noted that the use of controls is stressed in this experiment, and in others, as is the isolation of single variables in the design of experiments. Having learned from the experiment on nutrition that the organism needs a vitamin before it can grow, the student focuses on the compounds themselves and tests the possibilities, finally narrowing them down to vitamin B-1, which is required for the growth of *Phycomyces*.

Synthesis of data accumulated during the course of the block is stimulated by questions and class discussion. Moreover, whenever possible, the attempt is made to relate these data to things learned in other courses; that is, biology should be part of the mainstream of the curriculum. For example, during the study of growth, curves for the growth of human populations are discussed and the ideas of Malthus and other economic theorists considered. More obviously, the close relation of biology with chemistry and mathematics is one aspect of these interdepartmental associations that can be furthered. Biology does not exist in a vacuum and must be shown to illuminate, as well as draw fuel from, other disciplines.

Communication, as an element in the methodology of modern science is considered through the provision of references during the course of the exercises, as well as in bibliographies at the end of sections. Wherever possible, the references are to well-written, yet rigorous, reviews of current information, such as those found in *Scientific American*. Another class of reference is that which is designed to stimulate interest and widen horizons by exploring how microbiology impinges upon other fields, for reasons discussed previously. Thus, books like "Rats, Lice and History," by Hans Zinsser, and "The Next Hundred Years," by a group of scientists from the California Institute of Technology, fit in this category.

What might be called "unfinishedness" should be a vital part of any course purporting to teach science. In other words, answers to questions beget more questions, and only through this means can we probe deeply into the unknown. This principle is approached in the exercise on interactions wherein competition between soil microbes is studied. The student proceeds from the raw observation that inhibitory zones are produced in his

cultures to the increasingly subtle questions concerned with the mechanism of the effect. Is it attributable to antibiotics? To infection by virus? Or, perhaps, other mechanisms exist about which we do not know at present. It is not hard in any biological experiment to introduce the notion that loose ends remain —in fact, it is hard to avoid! However, it is more difficult to convince a student that these loose ends, which make up the "unfinishedness" of which I spoke, ultimately comprise the warp and woof of our science. Patient exposure of one question after another leads us to broader, if not complete, understanding.

Incertitude

Our society has arrived to the point where few laymen will dispute the power and productivity of the scientific approach, and the laboratory block certainly contributes to this development. However, the scientist has the responsibility to redress the balance, up to a point, in that there is incertitude at the core of any scientific investigation. In fact, much of the challenge and adventure in experimentation derives from the scientist's attempts to minimize, or to circumvent, these built-in pitfalls. There is, to use Heisenberg's term, an "Uncertainty Principle" which influences biological work, as well as the one which affects physical experimentation. This principle might be called the "Tyranny of Techniques" for, though these are usually in the scientist's service, he is to an extent their prisoner. This is illustrated in the study of growth where several alternative methods of measurement are presented. I have already mentioned the curve obtained by the use of cell counts, but measurements of dry weight, and radial and linear extension, are also used. Which of these represents growth most accurately? A growth tube for measuring linear extension is illustrated in Figure 9. It is suggested, as a result of these experiments that each technique has certain advantages and that it is frequently necessary to employ more than one in order to fully characterize a biological process.

Another aspect of science which involves incertitude is reflected in the data the students collate during their work in the section on growth, as can be seen in Figure 7. When each of the measurements is plotted it becomes obvious that there is considerable deviation from the mean in replicate samples. Because scatter

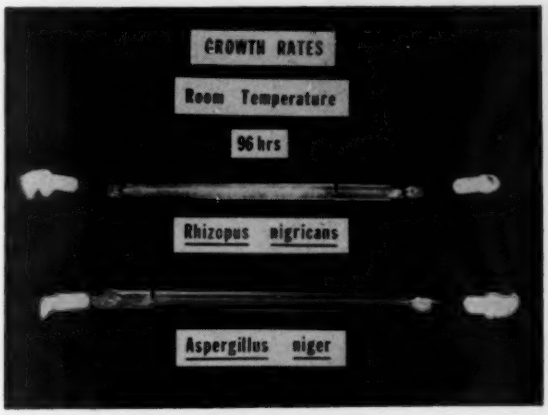


FIGURE 9

is inherent in measurements of this kind the need for replication and repetition of experiments is underlined. The reasons for this variation are concerned with the fallibility of the human senses through which all our observations are filtered. Moreover, the techniques themselves, and the equipment, all contribute to the departure from accuracy which is inherent in data collection. But there are ways of understanding and contending with these difficulties and this block, and the others, discuss these means within the framework of experiments performed by the students themselves, instead of through "canned" data. This is another place where open-endedness is encouraged in that statistical calculations, which mitigate some of these difficulties, are described. These include the standard deviation and coefficient of variation and, in addition, the meaning of such terms as precision and accuracy is discussed. Clearly, here is an opportunity for fostering integration with the teachers of mathematics!

An excellent summary of the status of incertitude in science, as I see it, is provided in the following quotation from the historian H. J. Muller, "If the pronouncements of reason are always fallible, they are always corrigible too; and in science it has created the one orthodoxy that welcomes and thrives on constant correction."[3]

Possible Limitations in Curriculum Revision

Our enthusiasm for curricular revision should not outstrip our critical faculties. There are limitations in any teaching process,

[3]Muller, H. J. "The Uses of the Past," Oxford University Press, 1952, page 287.

and the recognition of these will help in evaluating our experiences. First, the block is an intellectual concentrate and as such may prove unassimilable to some students. Even good students may find it difficult to work with crowded agendas, like the one reproduced in Table 4. Fortunately, turgid schedules of this kind are not the rule, but deliberate efforts must be made to retain the coherence of the block as a whole through frequent discussions.

Table 4

Agenda for Day 13

Day 13 (Wednesday)

Growth

Yeast cell counting and media inoculation

A. Population Growth
Count yeast cells using procedure from previous day. Student No. 1 will do Part B. Colony Growth, while his partner counts yeast cells. Then, while Student No. 1 counts yeast cells, Student No. 2 will do Part A. of *Nutrition*, Auxanographic Technique.

B. Colony Growth (Part 2)
Inoculate three plates of potato dextrose agar: Place a small number of spores of *Penicillium* in the center of one plate, spores of *Rhizopus nigricans* in the second, and spores of *Aspergillus niger* in the third plate. Incubate them at room temperature.

C. Growth Rates
Inoculate four growth tubes, two tubes with one fungus and two tubes with another (both fungi to be chosen by the squad). Incubate one tube containing each organism at 12° C, and incubate the second tube containing each organism at room temperature.

Nutrition

A. Auxanographic Technique
One student in each squad should make a saline spore suspension of *P. blakesleeanus* and then pipette 0.5 ml, after mixing, into each of the eight flasks of media (See Media Preparation, *Nutrition*, Part A. 2.)

Then, let us admit that the introduction we provide students to the way science progresses is in the way it *sometimes* progresses. We cannot predict how future breakthroughs will occur no matter how thoroughly we reproduce the history of such events. Creativity, in any field, cannot be viewed out of the context of the times, and pat analogies have a way of disappointing us.

Furthermore, how does one teach the personal elements in science, like intuition, integrity, and dedication? How are these measured? If measurement proves to be possible, will we be able to develop latent abilities in students or alter existing patterns of behavior through laboratory experiences? Can we guage the effects of our teaching with precision enough to use the data as an aid in charting our future courses? To be sure, some of these questions are being approached through testing and analysis of a sophisticated kind, under the sponsorship of the Steering Committee of the BSCS, as well as of the Committee on Innovation in Laboratory Instruction, and I am certain that valuable information will be obtained. However, it seems to me that the measure of our success will be the extent to which we have succeeded in illuminating the methodology of science and in stating the questions that we must answer in the realm of the personal elements of the scientist.

To conclude, although this principle should need no reiteration before an audience of teachers, no creation of paper and ink can be automatically evocative of the ideas outlined above. These must be elicited by a teacher who perceives the intent of the exercises as well as their mechanics. The other side of the coin may be that this block is purely mental, in that the ideas espoused are impractically applied. For this possibility I am prepared and ask only, as I am sure my colleagues do, that you teach us as well as your students.

Animal Growth and Development

• *Florence Moog, Washington University, St. Louis, Missouri*

The central purpose of the laboratory block program is to give high school students a chance to learn about the nature of science by studying problems in the way that scientists study them—that is, by doing research. Though one cannot reasonably expect that any new investigations can be carried out in a few weeks in a high school classroom, the

laboratory blocks nevertheless aim to give students a chance to pursue problems that will appear fresh and original to the students themselves. The students will engage in a valid search for facts that are unknown to them at the start. They will carry out the necessary procedures themselves, they will make their own observations (and their own mistakes), they will record their findings, and they will attempt to interpret the results they obtain.

The special subject of this paper is a block devoted to questions of animal growth and development. This general subject is not the easiest to adapt to the stringencies of the high school laboratory, but there are two good reasons for the attempt to include it. For one thing, the topic is of obvious interest to young people of high school age. They are themselves growing and developing animals, and so the subject, if presented in the right light, has an immediate appeal to them. The second reason is a less special one: the fact is that the area of embryonic development embodies the most challenging problems in the whole realm of science. Any area of science can, of course, be made challenging to the youthful mind as, we hope, the other blocks in this series also demonstrate. But what can surpass the challenge of an incubating hen's egg? The fresh egg appears to contain little besides the yolk and white so familiar in the kitchen and on the breakfast table. But if the egg is put into an incubator, in three short weeks there emerges, under its own power, a miniature chicken complete with wings and feathers and bright eyes and a loud voice and a lusty appetite. The most rigorous problems in modern biology converge in the problem of what happens in those three weeks, particularly at the beginning of the period. We are still a very long way from being able to understand what happens in the early development of any animal. We have probed deeply into the secrets of the atom, we are almost ready to put a satellite into orbit around the moon, but we shall not soon be able to make a chicken in the laboratory. If there is any area in science that can challenge a youngster's imagination, this is it.

The foregoing is entered as a defense of the inclusion of animal growth and development in the laboratory block program, since the material that must be used is relatively cumbersome and inconvenient. Dr. Sussman's microorganisms have the advantages of small size, rapid growth, and convenience of storage. Dr. Richard's materials have the substantial advantage of lending themselves to a program in which every period is a self-contained unit. Developing organisms, on the other hand, dictate the time schedule to the observer. One usually has some choice about when to start, but once development is underway, the observer has no choice but to follow along. The developing embryo does not take time out for Sundays, holidays, or special school assemblies. The best that can be said for this situation is that it impresses on the student's mind the fact that development is, indeed, a continuous flow of change.

The special characteristics of the material mean that the selection and arrangement of subjects in the block is dictated partly by the requirements of time. This block on animal growth and development is, therefore, not really an integrated research project like those on bacterial growth and on the interdependence of structure and function. Rather, this block is better described as a series of studies which are all devoted to some aspect of the general problem of development.

The Subject Matter of the Block

Since frogs' eggs can be obtained by the technique of induced ovulation during the greater part of the school year, they are the subjects of a considerable part of the block. Here the students' first assignment is to look at the developing eggs carefully and make out for themselves what happens as the egg converts itself into a tadpole. This exercise is a most valuable one, since a keen power of observation remains one of the scientist's most important tools. If the students make their observations with sufficient care and skill, they will be able to discover for themselves that development is truly epigenetic—that is, that difference and complexity appear in what at first seemed quite uniform and simple—and also that development proceeds from the general to the particular.

Frogs' eggs, of course, also lend themselves to numerous experiments. One of the simplest and most interesting experiments involves study of development of the eggs at different

temperatures. At first the problem of providing a series of reasonably well-controlled temperatures in the high school laboratory appeared insoluble. The project associates in the laboratory block program have, however, solved the problem very simply, with a tall stack of polyethylene dishes in a heated box placed in the refrigerator. With this simple piece of equipment, the students can set out to determine whether certain stages of development are particularly susceptible to high or low temperatures and whether the size or structure of the tadpole is affected by the temperature at which it develops. These are legitimate problems which have been subjects of bona fide research within the past 25 years. This temperature series also has the incidental advantage that it allows the students to see more different stages of development than they could see if they used only one temperature and looked at the embryos only at 24 hour intervals.

Another experiment is on the subject of parthenogenesis, in which a number of newly-ovulated eggs are pricked with a fine needle. Here the students address themselves to the problem of determining whether the sperm is essential per se, or whether the effect it exerts in penetrating the egg surface is separable from the act of introducing a set of chromosomes. A very simple experiment also suggested in the block is on the effect of crowding or "population pressure" on development. In this case the students simply place different numbers of eggs in a limited volume of fluid and follow what happens. Another possibility is to study development in the absence of oxygen, using a fairly simple apparatus that has been designed for this block. Such a study is feasible because frogs' eggs are capable of carrying out the earliest stages of their development without oxygen. A variation on this idea is the investigation of development when the eggs are put into fluid containing some chemical substance known to inhibit the utilization of oxygen.

One more exercise to which frogs' eggs lend themselves well is the observation of the development of a function—muscular movement. In making these observations the students take early larval stages and poke them gently with fine bristles to determine whether the larva will respond and what kind of response it will make. Thus the students can see how the ability of the tadpole to swim is gradually formed out of wriggles, feeble at first, that gradually become faster and better controlled.

The chick embryo, of course, will also be a subject of this block. Although hens' eggs are rather expensive and require a good deal of space as well as a simple incubator, the practical problems can be kept down to manageable proportions if each team of two or four students is given just one egg each day, and is charged with the responsibility of removing the embryo carefully and demonstrating it to other teams who will have different stages. Again, observation is of basic importance here. By observing carefully, the students will be able to deduce for themselves the same principles of development that the frogs' eggs made manifest.

By comparing the chick and frog embryo, moreover, the students will be able to teach themselves the lesson that evolution is conservative, for it is obvious, even to casual inpection, that frogs and chicks at very early stages are much more like each other than they are like the adults they will later become. On the other hand, special study of the chick embryo in relation to its shell and food and water source will give the students an insight into the problems that vertebrate embryos had to solve in the transition from life in water to life on land.

Though chick embryos are more difficult subjects for experimentation than frog larvae, a few simple studies are nonetheless possible. Although the hen's egg requires a constant temperature for development, individual parts of the body are actually responsive to temperature changes. The students can study this phenomenon by opening eggs that have been incubated for about 48 hours, and placing them in dishes containing salt solution at different temperatures, and then counting the rate at which the heart beats. Other simple experiments involve the demonstration of the activity of oxidative enzymes by histochemical tests applied to living embryos that are lifted off the yolk and placed in small dishes of fluid. The tests suggested (the Nadi reaction for cytochrome oxidase and reduction of Janus green for dehydrogenases) will enable the students to determine that the embryo of 48 or 60 hours' incubation already has high oxidative activity which is distributed in a

non-uniform way over the body.

The role that hormones play in controlling developmental events is a continuing theme throughout the block. It appears first of all in the technique of induced ovulation by the administration of pituitary glands to a mature female frog. Time permitting, the students might carry out this technique themselves, or it might be demonstrated to them. The role of the thyroid hormone in embryonic development can also be studied. In the chick embryo, it is a simple matter to eliminate thyroid function by injecting a little thiourea under the shell at about 11 days. This drug suppresses the production of thyroid hormone with the consequence that the embryos lag far behind the controls, do not hatch at the normal time, but may remain alive in the shell for several days beyond the normal hatching time. By opening injected eggs at various times after treatment, the students can figure out the nature of the effect for themselves. If they have time, they might also dissect out and examine the thyroid glands, which become tremendously enlarged, or goitrous, because the normal feedback mechanism that regulates the flow of thyroid-stimulating hormone from the pituitary has been interrupted. Another experiment that involves the thyroid hormone is the acceleration of metamorphosis in frog tadpoles, an exercise that is already familiar in many high school laboratories. Discovering all the effects that thyroxin exerts not only challenges the students' powers of observation, but, if time and facilities permit, the students may also be set to determining the relative potencies of triiodothyronine and perhaps other analogs of thyroxin.

Another experiment that never fails to arouse the enthusiasm of students is the speeding-up of sexual differentiation in newly-hatched cockerels by the administration of the male sex hormone, testosterone, or of a gonadotrophic hormone preparation. By examining the chicks over a period of two to three weeks, the students will discover that the treated chicks grow faster than the controls, their combs develop precociously, and they display signs of rooster-like behavior (trilling, crowing, fighting, among themselves) at a very immature age. If autopsies are carried out at the end of the experiment, the students will see that one type of hormone treatment makes the testes bigger than those of the controls; the other makes them smaller.

In addition to the work on embryos, there is also a series of experiments on regeneration, which essentially represents a return to embryonic conditions in differentiated animals. One organism in which these phenomena can be studied is the frog tadpole. At almost any stage, cutting off the tail will result in the regeneration of a new tail within the time that the block allows. More familiar to most high school teachers, perhaps, is the use of *Planaria*. As with the tadpole, the students can simply follow the results of cutting off a part of the animal, and they can also set up a series of additional "unknowns" by varying their cuts according to a series of suggested patterns. Similar experiments can also be performed on *Hydra*, with which the students can learn by their own efforts that most, but not all, parts of the body have the capacity for regeneration. *Hydra* can also be used in an interesting experiment on reconstitution in which several animals are cut into the smallest possible pieces. These pieces, if they are kept close together, will seal themselves into an at first formless mass from which two or three hydra soon resolve themselves. This phenomenon of reorganization of a pattern from a disorganized mass of cells or fragments is also displayed by embryonic tissues and is the center of a great deal of research interest at the present time.

Growth in itself, as a phenomenon separate from developmental change, is not given much weight in this block. There is, however, one study on the growth of a population of *Hydra* in which the students can examine some of the factors that limit or promote the growth of a group of individuals.

This then is an outline of six weeks of work that we hope will be rewarding to both students and teachers. If the schedule as outlined seems overcrowded, a certain amount of selection is easily possible, and some of the experiments described are optional or can be performed in different ways. On the other hand, most of the experiments are of such a nature that they can be extended by keenly interested students. Or, various kinds of studies can be combined. For example, one class might want to study the effect of respiratory inhibitors on regeneration. There are plenty of opportunities for setting up new experiments not included in the block.

The Principles of the Block

A course of observations and experiments like that just described might be a stimulating experience, or it might be a fiasco. Much depends on the approach that is used as well as on the skill with which the teacher implements that approach. Since the approach is the concern of the designers of the block, we might now consider how we propose to go about the work of this block. We shall begin by raising in the students' minds a deceptively simple question: What happens when an egg converts itself into an animal? The attempt to answer this question is the unifying theme of the block. This attempt involves several important principles.

First, there is the need for careful and accurate observation. Youthful minds, particularly, are apt to pick up the notion that research of any importance requires very expensive equipment. Certainly no one who understands modern science would want to denigrate the use of costly apparatus like the ultracentrifuge or the electron microscope. Until these instruments became available, critical areas of biological interest remained closed to investigation. But students getting their first introduction to biology need to understand that the scientist's most powerful tool is his mind aided by the hand and the eye. It is, after all, this triumvirate that has brought us up from the apes.

Once some reliable observations have been made, a question must be elicited: Why does development go on at a certain rate? Why does a limb bud appear now and not sooner or later? Is the occurrence of one event essential for the occurrence of a subsequent event? Such questions bring us to the second principle. Students left to themselves tend to raise impractical questions; even bright college seniors, asked to design a semester's research project, often come forward with a plan that could scarcely be executed in a decade. So the students must be led to see that it is not enough to ask a question—the question must be cast in some specific form in which it can be answered.

The study of development of swimming ability in tadpoles, cited above, may be taken as an example. By poking at the developing larvae with bristles, the students can see that the larva at first bends sluggishly to one side in response to stimulation, then flexes more rapidly from one side to the other, and finally succeeds in making enough rapid sinuous movements to propel itself forward—to swim. Now one might ask: Are the sluggish ineffective bending movements of the young larva a form of "practice" by which the larva learns to swim? Put that way, the question is hard to deal with. But we can turn it around: If the early movements were prevented, we may ask, would the tadpole subsequently be unable to swim? This question is capable of being answered in a simple way by raising the larvae in a narcotic solution too weak to interfere with their structural development but just strong enough to immobilize them. Under these conditions the larvae will grow into well-developed but motionless tadpoles. When they have reached the stage at which the controls swim actively, the experimental tadpoles are washed free of the narcotic. By watching the tadpoles at this point, the students can determine whether the animals are able to swim despite their lack of previous "practice."

A third important principle arises out of the consistent use of controls. Controls are emphasized so frequently in all the blocks in this series that the students should be able to acquire a firm understanding of the conditions under which valid conclusions can be drawn from an experiment. One might even venture to hope that this understanding will have some transfer value, so that the students might develop a healthy skepticism concerning the kind of "experiments" that are every day being invented on Madison Avenue.

The fourth principle, and perhaps the most important, concerns the interpretation of results. Too many people look upon the scientific method as a kind of applied magic; you perform certain operations, you read off the results, and your problem is automatically solved. But this is far from being true. There have been instances in which two scientists have raised the same question, carried out the same procedures, obtained the same results, and then come to diametrically opposite conclusions. More than the simple ability to obtain results, the ability to see what one's results really mean is an essential attribute of the productive research scientist.

Even at the relatively simple level of the experiments in this block, the interpretation is not generally obvious. Take the experiment

on thryroid inhibition as an example. We know that substances like thiourea block the production of the thyroid hormone in mammals. Administered to incubating hens' eggs, thiourea severely retards the development of the embryo. Does this by itself prove that the thyroid hormone is essential for the normal development of the chick embryo? Of course it does not, and a few students will see this point on their own. By and large, however, it will be up to the teachers, through discussions, to lead the students to realize that a valid conclusion does not arise automatically out of the results; rather, it needs to be cautiously reasoned out and sometimes tested by further experimentation.

This point introduces what seems to be one of the few inherent weaknesses of the laboratory block program. The aim of the program is to give the students the experience of doing research, of being scientists for a day or for six weeks. But here a dilemma thrusts in its horns. A working scientist begins with extensive reading and discussion and study that give him the basis for designing good experiments and also give him a background against which he can interpret his findings. But the high school students must obviously cut this essential step to a bare minimum. If they were to prepare themselves fully for the "research" problem they are to carry out, they would find out the expected results of the study; and then the main point, of making the students search for facts unknown *to them,* would be lost. The difficulty appears to be intrinsic and unavoidable; we must accept it, but I think we should honestly face up to it. It would be useful if the teachers would hint gently, now and again, that though the laboratory block may be a fairly sophisticated kind of make-believe, it is make-believe, nonetheless. There is a certain tendency nowadays to over-glamorize science as a means of attracting immature young minds. The block program should not be used in such a way as to contribute to that tendency.

Certainly I do not offer this point of view as a fatal or even serious criticism of the block program. I have invested a good deal of my own time in the program because I believe in its possibilities. These laboratory blocks, if they prove manageable in actual practice, have the potentiality of bringing the students much closer to the true spirit of science than any conventional method of demonstrating known facts. Of course it must be recognized that no technique can be better than the teachers who use it. Granted that the blocks are handled with sufficient skill, however, one may hope that high school laboratories all over the country will become theaters in which students can learn about biology by themselves acting out the parts of biologists.

The Interdependence of Structure and Function

• *A. Glenn Richards, University of Minnesota, Minneapolis*

Understanding of the research method of learning is, today, so disparate from the study material of most American high school students that a test group which had just completed pretesting this laboratory block asked in the "candor" session, "Is this really real or is it a lot of hooey?" This was a picked group of exceptional students. Almost all of them did exceptionally well with the experiments per se and in the discussion periods. But, we had jarred their TV-formed notion of what a scientist is and what a scientist does; they wanted reassurance. They had, we felt, advanced a long way toward understanding the inherent nature of scientific research.

Of course, the students got reassurance, and all of us who form the Committee on Innovation in Laboratory Instruction have since tried to write this reassurance into the manuals the students will be using. The experimental approach, to be used by tenth-graders, is novel as we all realize. In order to introduce it to students so young we have been willing to reorient our own thinking (to the tune of months of work). Curriculum changes such as these laboratory blocks are, we think, a promising beginning on the orientation of high school students toward thinking for themselves in situations where there won't always be back-of-the-book answers to all questions. In other words, our objective in all of the six-week special laboratory blocks for tenth-grade biology classes is to give the students a genuine research experience.

The result of our study and pretesting is the presentation of biological laboratory material we are describing to you today. The material was tested at several places in the United States this spring. In these laboratory blocks we use relatively simple phenomena from many phases of biology as problems. We introduce the students to methods actually used by research workers. We induce the students to think for themselves, to criticize, to interpret, and to evaluate what they are doing. All of this is, of course, what research workers do. Necessarily for such young researchers we have to give step-by-step instructions that take them from the familiar to the unfamiliar and are spelled out with clarity. The reading and formulation of experiments, necessary first steps in research, we have to do for them. But the chain of events that makes up an experiment which will, perhaps, solve a problem are either described in the laboratory manuals or made known to the teachers so that a follow through to some end point is assured.

Essential to the preparation of these manuals has been the development, largely by the Project Associates, of simple and inexpensive equipment which is still of acceptable research caliber. Some of these items are shown here as text illustrations.

In six weeks of working on one topic of biology these laboratory blocks will have let the students experience a valid research project, including evaluation of data. None of these exercises are "busy work." None of them are made hard to do for the discipline value of difficult work in and of itself. Most of us will agree that difficult work can at times have its salutory effect on students, but our purpose in these blocks has not been to aim the exercises toward a goal of difficulty in working with the hands and/or the mind. We have tried to stimulate, not difficult thinking, but *original* thinking. An invalid "yes" that a student tries to justify by a train of thought derived from his own experiments, observations, postulations, and conclusions has, we feel, a long-run value larger than that of another student who, by reading a book where the answer can be found, has produced a correct "no," and offered it in class. The first student can be shown wherein he is wrong, making the chances of his correcting his own thinking the next time that much better. The second student, who is at a loss for what to do without a reference to consult, simply cannot do research without reforming his thinking. Research is a forging ahead from the foundation of reference into the unknown. Those of you who have been audience, referees, or sponsors of Science Fairs know how dampening an inspection of the projects can be. Some of the projects are really good and show a promising youngster, but so many of the projects are sheerly, and merely, hard work. They give evidence of about as much original thinking, which is a basic tenet of research, as is required to engrave the Lord's Prayer on the head of a pin.

As the laboratory blocks are now set up, the teachers are supplied with the answers which are known to science. But this fact does not keep the experience from being original research for the students; it is original to them. In addition the students work on some experiments in which no answer beyond a "working hypothesis" is known today. At a number of points in the six weeks of experimentation a project will, deliberately, be left "open-ended" so that students can inquire further. They can go as far as their spirit of inquiry and their free time allows, either further into what is already known about the problem or, in some cases, further into what none of us understand.

All of the laboratory blocks being developed by the members of the Committee on Innovation in Laboratory Instruction are similar in outlook and logic. This is true of the four blocks being discussed here this afternoon and of the others still in the course of preparation. Of this first four blocks, namely, "The Interdependence of Structure and Function"; "Microbes: Their Growth, Nutrition and Interaction"; "Animal Growth and Development," and "Plant Growth and Development," all of which are now ready for classroom testing, the operational technique for the structure-function block, developed by the author, does differ in one important *practical* aspect from the other three blocks mentioned above. In the other three the subject matter involves raising organisms, plant, animal, or microbe, and hence requires careful scheduling of experiments. The appropriate organisms must have time to grow to the appropriate stage for which they are needed. Most of the experiments in these three blocks,

then, have continuity. They require nearly daily attention over a period of days or weeks. Such day-by-day observation, measurement, and recording give the students valuable, and valid, experience in one kind of "real research."

The subject matter of the structure-function block, in contrast, permits the work of most periods to be a self-contained unit. The self-contained unit of work is also no stranger to the real research laboratory. Since, in the structure-function block it was not necessary to allot a portion of the laboratory time for growing organisms, we can and do cover more individual subtopics.

To describe the structure-function block in more detail it will be necessary to treat it section by section. But before beginning this segmentation I do want to make the point, or perhaps reiterate it, that a section lifted out of context would not make complete sense without the understanding of the structure-function problems worked out in the preceding sections. In other words, the block is not a compilation of scattered problems brought together under one cover. It is an orderly piling up of examples which, on being worked out, do explain why the structure and function of living matter so often show such striking complementarity.

Section One: Simple Levers: In defining and having the students work with the four important components of a lever system—lever, fulcrum, force and load—the principles and the effects of modifying the different components are studied and discussed. Then we consider the human arm as a lever, do experiments that illustrate its strength, leading from this into a discussion of the advantages resulting from such a structure as the arm. We have made a simple apparatus available that will permit making strength determinations of either stronger or weaker individuals. An arm is fastened to a lever and the lever length and load varied for making these determinations.

Calculations from data recorded and the plotting of data are introduced, then we de-

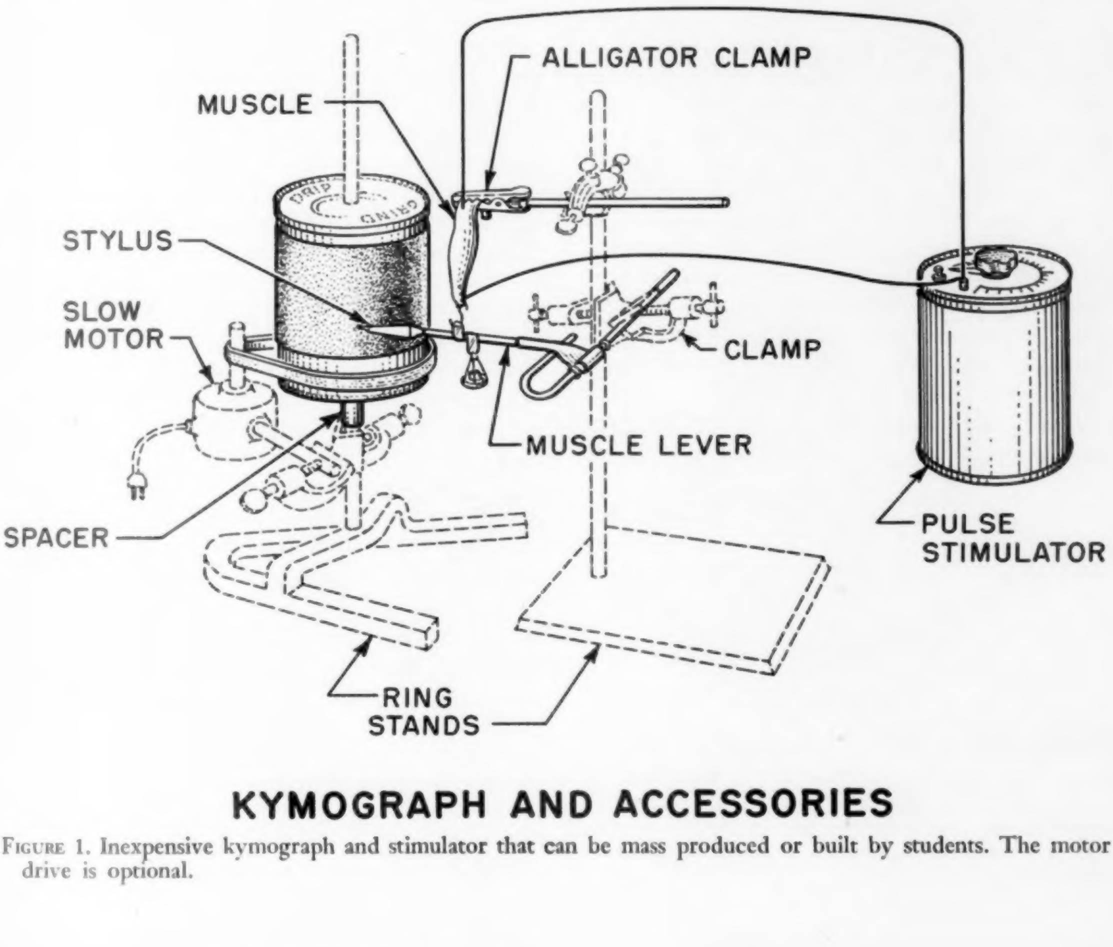
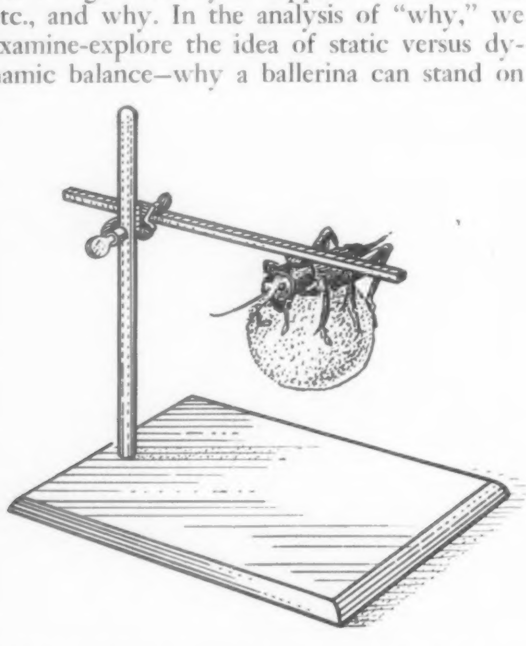


FIGURE 1. Inexpensive kymograph and stimulator that can be mass produced or built by students. The motor drive is optional.

vote a full discussion period to a consideration of the kinds of errors which can be made. Blunders, useless measurements, systematic errors, random errors are each taken up in turn and examined. The students are expected to learn and to keep in mind at all times the multiplicity of ways of being "wrong" and the extreme difficulty of being sure their data are valid.

In other periods we examine muscles by dissection and make mechanical recordings of the well known frog nerve-muscle preparations. These experiments lead us into an analysis of quantitative versus qualitative, objective versus subjective data. We can now discuss the differences between objective and subjective data, and we can recognize how and where precisely and poorly-controlled measurements differ.

Section Two—Locomotion with Levers: This section examines the mechanical factors involved in standing, walking, and running in animals with two, four, or six legs. First the students work out the qualitative factors by considering such experiments as the number of legs necessary to support a table, a man, etc., and why. In the analysis of "why," we examine-explore the idea of static versus dynamic balance—why a ballerina can stand on one toe whereas most of us need at least one leg, why human running is described as a "braked fall," but insect running is not, etc.



MOUNTED INSECT WITH BALL

FIGURE 2. A precision method for studying walking and running of insects. This simple and nearly costless set-up is closely similar to a currently used precision method of research. The ball is of styrofoam.

For deriving quantitative values in locomotion we use cockroaches and a miniature race track for our small runners. Since insects are not warm blooded animals this experiment lets us introduce an additional experimental approach, i.e., the effect of temperature on the activity of cold blooded animals. Cockroaches chilled to inactivity in a refrigerator show all the gradations from no movement, slow runs, faster runs, and full speed as their temperature rises. Then we use the measurements the students have made in the course of this experiment to introduce them to statistical analysis of data.

Next we study indirect movements with levers, using the flight of birds and insects for our observations and experiments. Excellent slow-motion pictures of bird flight are available. These we watch, discuss in terms of structure-function, then watch again. The duplicated observation demonstrates how much more you can see when you know what to look for. In subsequent periods the structural basis for the observed movements in flight are keyed in with appropriate manipulations and dissections of wings and other functional body parts of both birds and flies so that the students can determine the differing degree of indirection involved in the flight movement of these two phyla of animals. In birds, muscles move the wings which in turn move air and hence cause flight. But in most insects the main flight muscles do not attach to the wing at all; instead they perform by changing the shape of the thorax which in turn moves the wings that move the air that moves the insect.

Section Three—Movement without Levers: By definition a lever must be relatively rigid; therefore non-rigid animals or organs must perform their functions of movement without levers. We observe the crawling of earthworms, dissect the worms, and examine slides to observe the structures which let the earthworm move. Then we study the pulsation of blood vessels, breathing and lung action, the heart and circulation, pulse rates as a function of exercise to amplify on this sort of movement without levers. We conclude this section with a study of the proboscis of flies.

The fly proboscis permits an observational

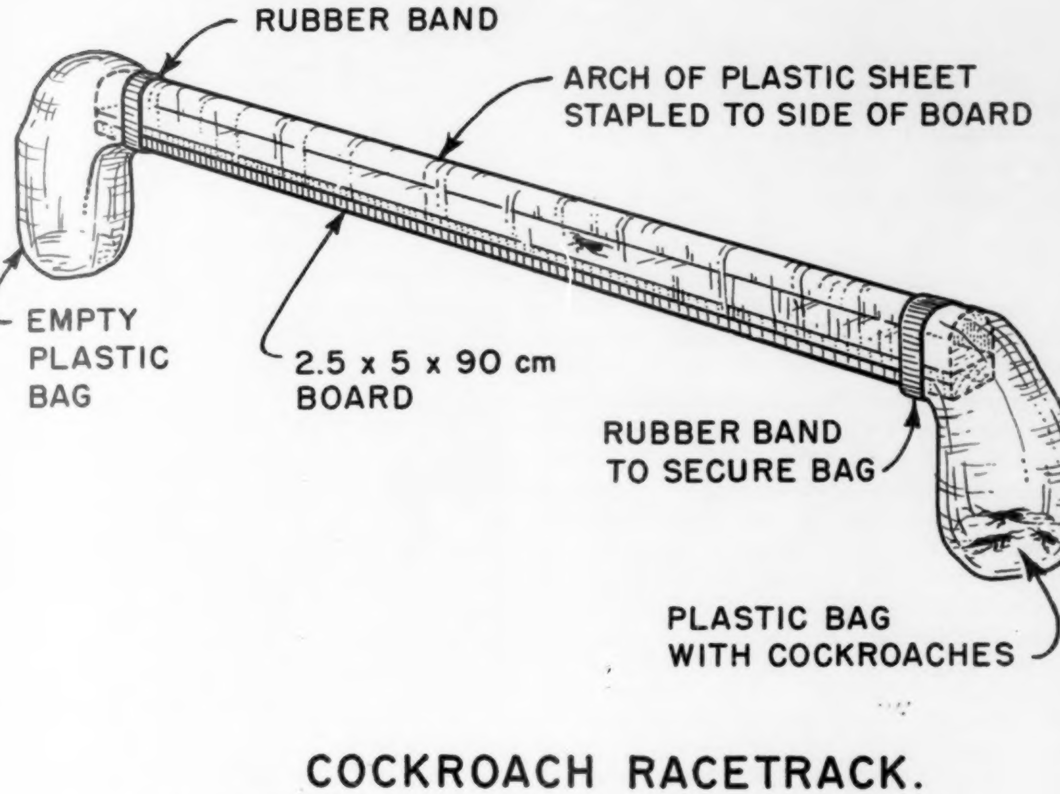


FIGURE 3. The cockroach racetrack from which cockroaches do not escape.

spread from watching it in action with the unaided eye to dissection and examination of the minutiae of its parts with a microscope. With appropriate discussion, this range of observation permits the formulation of a series of experiments offering a successive approach to the correct answer.

The fly proboscis is particularly good laboratory material for this step-by-step purpose since the cause and effect of movement of this organ are not immediately apparent. Muscles elevate the proboscis, but there are no muscles for lowering it to feed. The students feed their flies, so obviously the flies can feed without muscles for lowering the feeding organ. They place nooses, first around the neck, then around the junction of thorax and abdomen, in order to examine the postulate of a pressure mechanism. They pierce the proboscis, yet feeding continues, which demon-

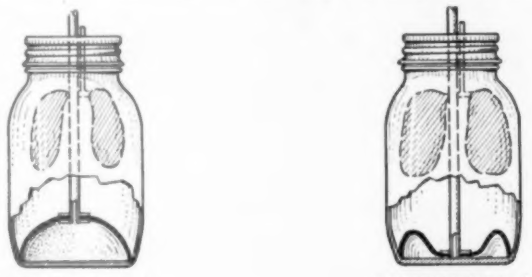


FIGURE 4. A model of diaphragm breathing made from a wide-mouthed jar, half a rubber ball, a rod, a pair of plastic "lungs," and some tubing and cement.

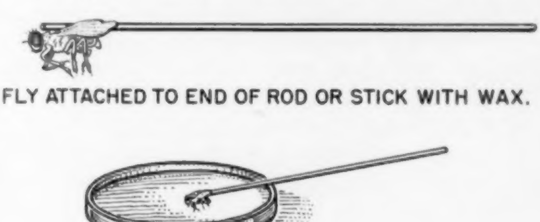


FIGURE 5. Live flies mounted on a stick with wax for easy and precise manipulations. Used for study of proboscis reaction and sensory response. This is another currently used precision research method.

strates to them that the pressure mechanism involved is not solely blood pressure. Piercing air sacs, however, does cause cessation of the response. The student is thus led stepwise to conclude that contraction of muscles in the abdomen produces air pressures which are transmitted through the tracheal system to the head. In the head the air pressure expands an air sac in the base of the proboscis and so forces the proboscis to extend. Step by step the students get the answer, just as the research scientists who worked this process out got it.

Section Four—Non-muscular Movements: For examples of non-muscular movements we observe and perform experiments involving ciliary and ameboid movement in plants and animals. Since one of the experiments involves an attempt to observe the streaming of protoplasm in *Chara,* which sometimes shows streaming and sometimes does not, we have a springboard for launching a discussion on the "inconstancy" of living material used in experiment. That the research worker may be completely "tractable" or precise and yet be hindered in his findings by "intractable" animals or material is knowledge necessary to the research worker in biology, and the students do not leave these laboratory blocks without having learned it—sometimes the hard way. When a student has been careful in every step of an experimental set up and still gets no results, this fact about research does make an impression—provided, of course, that the teacher sympathetically puts across the fact that in complex biological systems numerous experiments work only a certain percentage of the time.

Section Five—Movements in Plants: For these observations we do experiments on the opening and closing of pores into leaves and on a laboratory model that illustrates the rise of sap in a tree. The study of stomata gives us a method of demonstrating variations in technique for attacking the same problem. Each of half a dozen groups uses a different method of examining and measuring stomatal action. The reports and discussion bring out the fact that there are various ways, including inanimate models, of approaching the study of a particular set of phenomena. Each method has its advantages and disadvantages; all are arguable. The students are led to appreciate that commonly there is not just one "correct"

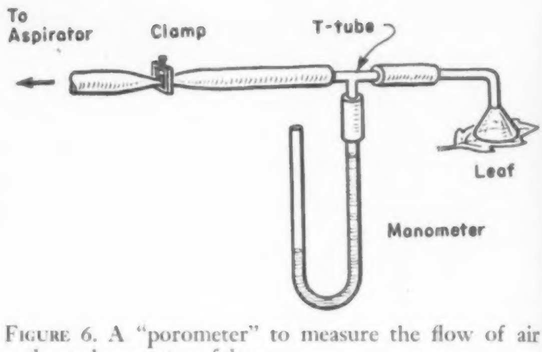


FIGURE 6. A "porometer" to measure the flow of air through stomata of leaves.

way of studying a particular object. Which method of study is "best" may depend on the equipment available, on the ease and speed with which the equipment can be used, on just what specific question you want answered, on other things. Again the point is made here that making precise quantitative measurements to derive an answer to a question that can be answered with equal validity through studies of a qualitative, relatively "rough" nature adds primarily to knowledge

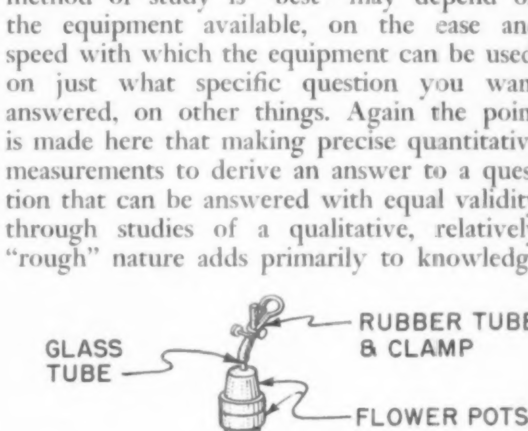


FIGURE 7. An evaporator made from flower pots, a stand, some tubing, a beaker, and some mercury. It is a model to illustrate the power of one of the factors involved in the ascent of sap in plants.

about the research worker, not about the problem at hand.

The study of ascent of sap in a tree involves only a model, and permits bringing out the point that a model which is satisfactory under one set of conditions is completely inadequate under a different set of conditions. Our "models" tend to be too simple—yet they are useful. This is discussed in class at some length.

Section Six—Muscle: The section on muscle in this laboratory block asks a great deal of tenth-graders in attentiveness. It does not, however, ask more than they can offer. The study of muscle leads to complexities that can faze mature research workers. Yet, skimming the surface in a study of this living material lets us demonstrate that seeing a process in operation is not necessarily understanding it, on the one hand, and, on the other hand, that even without complete understanding, with only a "working hypothesis" for a starting point, much valuable, enlightening work can be done. The students, on their own, make examinations of muscle down to as fine detail as their microscopes will permit, including observation of mitochondria in fresh preparations of the flight muscles of insects. Then their study is supplemented with a half-hour film that introduces some of the points determinable by electron microscopy and biochemical methods. The students are led to consider muscle both from the standpoint of what happens during contraction and of how stored chemical energy is converted into mechanical work. Muscle contracts actively, not passively like a rubber band. It is a system which develops force during contraction. It is also a system for burning sugars to get energy. In the film these points are explained to the extent that is known today, including what are now only "working hypotheses" on the finest points of the mechanisms.

In this same section, in order to prevent the possibility that students might conclude that complementarity of structure and function is peculiar to motion, we briefly consider enzyme action and the immunochemistry of human blood types. With permission from the parents (in those high schools where such permission is required) the students work out the steps necessary to determine their own blood types. Then they discuss the relevance of structure and function in this situation. We also call to the attention of the students the fact that *all* structure is not complementary to function, or is not immediately complementary to function.

Section Seven—Final Discussion: Here the students review the methods, logic, and criticism involved in their six-week research experience. The laboratory manual classifies the approaches used throughout the series under nine headings: observing, correlating, analyzing experimental measurements, designing specific experiments to test particular ideas, rationalizing data by comparing it with better known physical and engineering principles, making inanimate models, combining data from several sources, evaluating the validity of data, and using imagination. For each of the twenty-six exercises in the series the students list the approaches used. They discuss what approaches they found the most informative and decide whether or not approaches which were not used in a particular exercise could have been used with good effect.

The teacher is supplied with an analysis page under the headings above; so are the students. The teacher's page is filled in as a sample reference to what can be expected from the students in the way of understanding what they have been doing. Now, at the end of the series, the students should be able to place each experiment they have done under its relevant heading or headings. In a sense the analysis sheet, then, serves as a simple but telling sort of quiz. Its primary purpose and service, however, is to demonstrate to the student that he can grasp the meaning of an experiment performed and can define it well enough to mark it as pure observation, correlation, analysis of measurements, evaluation of validity, etc. In this way he arrives at a concept of how scientists think and work.

Plant Growth and Development

• *Addison E. Lee, The University of Texas, Austin*

The laboratory block on Plant Growth and Development begins with this introduction:

> "Mighty oaks from little acorns grow" is a familiar expression. It states a fact we all know. We know that any seed, alive and planted under favorable conditions, will grow into a seedling with roots, stems, and leaves, and that the young seedling grows and develops into a mature plant. In time the plant will produce flowers, then fruits, which will ultimately contain seeds. All of these facts have been observed many times. This is the life story of a flowering plant.
>
> The scientist, however, is not content with these simple observations. It is not enough for the scientist to observe that growth and development occur and that roots, stems, leaves, flowers, fruits, and seeds are formed. He is curious to learn "what," "how," "how much," and "why."

The study in this laboratory block is divided into five major areas. (1) germination, (2) measurement and patterns of plant growth, (3) internal organization of plants in relation to growth and development, (4) metabolism and nutrition in growth and development, and (5) regulation of growth and development—growth substances.

During the study of germination, the student first compares the percentage of germination with the percentage of viability (tetrazolium test). He is asked to suggest why these percentages may differ. This can lead him to suppose that factors other than being alive are necessary for germination, which forms the basis for later experiments to study these factors. Meanwhile, he observes the nature of germination of several different kinds of seed and learns that germination first involves water uptake (imbibition), then a resumption of active growth by the embryo, resulting in the rupture of the seed coat and the emergence of the young plant. He also compares the gross features of the various parts of the developing embryos of different plants. He then studies seed dormancy by comparing the germination of okra seed (a) untreated, (b) treated by scarifying the hard seed coat, and (c) treated with a sulphuric acid solution. It would now appear that many environmental factors are involved in germination. The student is now provided with data showing the permeability of polyethylene sheets to oxygen and the impermeability of Saran wrap to oxygen. (Polyethylene is more than 100 times more permeable than Saran to oxygen. Saran is 3 times more permeable to carbon dioxide than to oxygen. Brown, W. E. and W. J. Sanber, "Gas Transmission by Plastic Film," *Modern Plastics*, August, 1959.) He then sets up an experiment to compare at room temperature germination of seed wrapped tightly with moist vemiculite in a polyethylene bag and in a Saran bag. He also observes the effect of temperature by comparing germination of a similar batch of seed in a polyethylene bag placed in the refrigerator. Armed with data from these experiments, he is then challenged to design an experiment to determine the critical temperature for germination, the relationship between temperature and imbibition, and to compare these effects in different kinds of seed.

The effect of light on germination is developed into a fairly sophisticated experiment. The student first determines whether light has any effect on germination of two kinds of lettuce, Grand Rapids variety and Great Lakes variety. He learns that light is much more necessary for germination of the Grand Rapids variety than for the Great Lakes variety. He is then asked what kind of light is involved and is guided in the selection of proper light sources and light filters so as to determine experimentally that a specific area of the red light spectrum is important for germination of Grand Rapids lettuce. To help the student make the appropriate selections, it is necessary to provide him with specific information concerning light. This is essentially the same as what a scientist does when he finds it necessary to obtain information and learn new techniques from a different field of science in order to pursue his own investigations. He reads the literature of the different fields, and he consults fellow scientists in the allied fields where he requires information. In our investigation of plant growth and development we

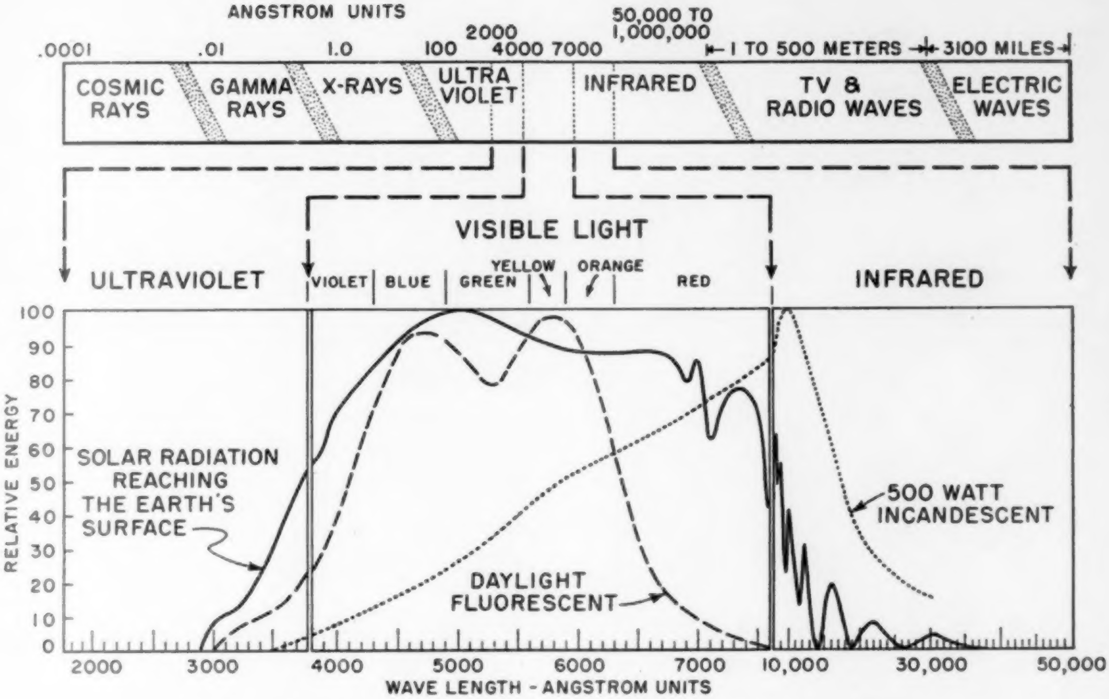


FIGURE 1. The electromagnetic spectrum and its relation to light.

stop at this point and discuss the nature and characteristics of light as shown in Figure 1. We then consider the production of artificial light and the control of light by the use of colored cellophane to filter out certain wave lengths (see Figures 2 and 3). By using appropriate combinations, we can produce four different bands of light as follows:

LIGHT SOURCE	FILTER (DuPONT CELLOPHANE)		APPROXIMATE LIGHT BAND
Fluorescent plus	300 MSC Dk. Blue	=	3900-5500 Å
Fluorescent plus	300 MSC Dk. Green	=	4700-5800 Å
Fluorescent plus	300 MSC Red	=	5800-6800 Å
Incandescent plus	Red & Blue above	=	7000- -- Å

After germinating seed of the variety of lettuce most affected by light under the conditions above, as well as with controls set up in the dark, the student is able to sort out the effects of near-red and far-red light on germination of Grand Rapids variety lettuce. It is suggested that this could be related to the influence of this light on the production of specific chemical substances, some of which may inhibit and others promote growth. (See December, 1960, issue of *Scientific American* for informative article by W. L. Butler and Robert J. Downs on "Light and Plant Development.") Since Grand Rapids lettuce is much more influenced by near and far-red light than Great Lakes lettuce, the student learns to be cautious in making generalizations. (See Figure 4.)

While the above experiments are being developed, the student begins to study the growth curve of a plant by measuring and recording the growth in length of stems, roots, and leaves of bean plants. (See Figure 5.) The student also learns where growth occurs, and repeating the old experiment of Sachs, he marks very young roots, stems, and leaves with equidistant marks and observes the distance these are apart after growth for a given period of time. (Figure 6.) He learns whether or not growth of the root occurs if the root tip is removed, thus emphasizing the importance of the root meristem. Class discussion at this point is designed to compare growth patterns in plants and animals and develop some understanding of the nature and cause of the *indeterminate* growth of plants, as well as the *determinate* growth of animals.

In the section on the internal organization of plants in relation to growth and development, the student studies the size and number

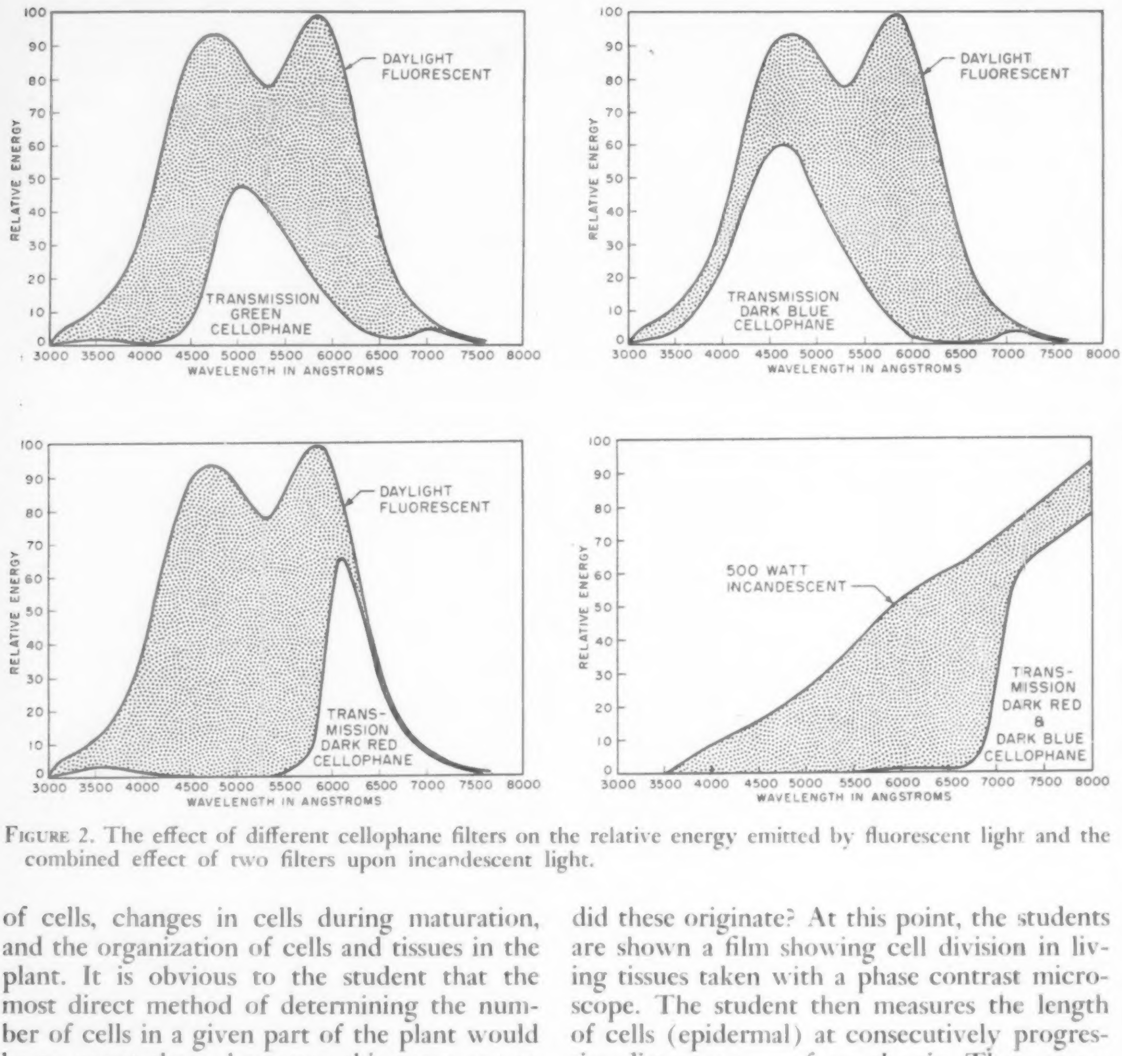


FIGURE 2. The effect of different cellophane filters on the relative energy emitted by fluorescent light and the combined effect of two filters upon incandescent light.

of cells, changes in cells during maturation, and the organization of cells and tissues in the plant. It is obvious to the student that the most direct method of determining the number of cells in a given part of the plant would be to count them; however, this turns out to be easier to say than to do. Therefore, an indirect, and less accurate, method is used. This involves marking 3-day old growing roots at a distance 1.5 cm from the tip, killing some of them, and allowing the remainder to grow for 3 additional days. These 6-day old tips are measured from the original mark and killed. Both 3-day old tips and 6-day old tips are cleared (the technique for clearing is given in the Appendix), and individual cells near the mark are measured (the technique for using an eyepiece micrometer and calibrating it with a stage micrometer is also given in the Appendix). The student can now determine that the cells at the mark of both 3-day tips and 6-day tips are of similar size. This being the case and since growth of the 6-day old tips makes it longer, it must have many more cells. Where did these originate? At this point, the students are shown a film showing cell division in living tissues taken with a phase contrast microscope. The student then measures the length of cells (epidermal) at consecutively progressive distances away from the tip. These measurements provide data to demonstrate cell elongation. Thus, cell division and cell elongation are shown to be fundamental to growth. The student is then given instructions for tissue maceration and after mascerating several kinds of mature plant tissue, is able to observe the many different kinds of cells (different types of xylem, phloem, parenchyma, epidermis, etc.) which result from cell maturation. He then investigates the organization of these cells and tissues by observing free hand sections of fresh plant material. Note the hand microtome we have developed for this purpose in Figure 7. The student has now investigated the fundamental processes which result in the structure of the plant—cell division, cell enlargement, cell maturation, and cell and tissue organization.

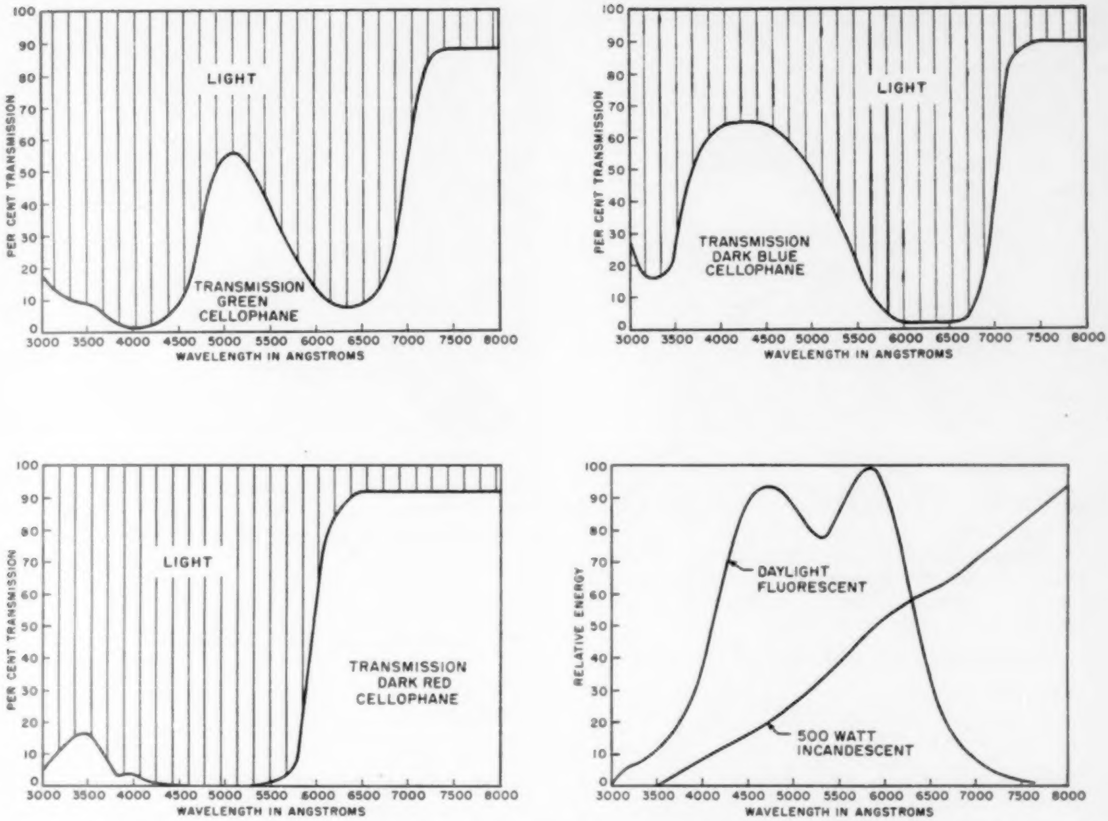


FIGURE 3. The percent transmission of light by various colors or cellophane and the relative energy curves of two common light sources.

However, structure and function are very much interrelated. Thus, in the next section, the student studies the functioning of the plant. He observes first the reaction of an enzyme (amylase) in corn embryos; then he measures respiration in seedling using a special

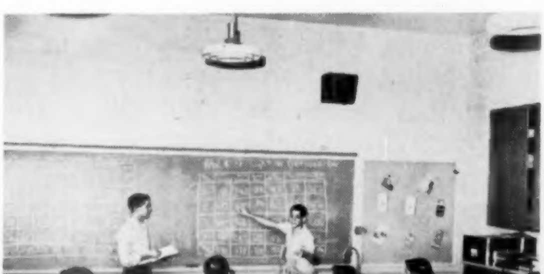


FIGURE 4. Students in Mrs. Marjorie Behringer's Biology class, Alamo Heights High School, San Antonio, Texas, summarizing data obtained with experiments on the effect of light on lettuce seed germination.

FIGURE 5. Students in Mrs. Marjorie Behringer's Biology class, Alamo Heights High School, San Antonio, Texas, plotting a growth curve from data obtained while studying this laboratory block.

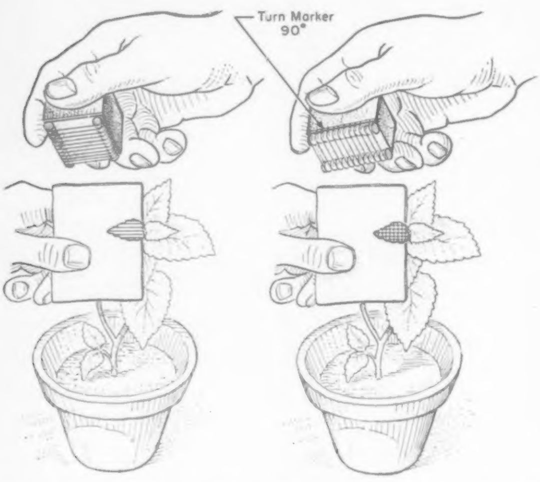


FIGURE 6. Special marking device with cotton thread wrapped around a machine bolt glued to two edges of a block. The thread is impregnated with fingerprint ink, and the device used to make equidistant marks on roots, stems, and leaves for growth studies.

Volumeter which we have developed, and detects cytochrome oxidase activity (using the Nadi reagent). He determines the factors (light, chlorophyll, and CO_2) involved in photosynthesis and observes the effects of mineral deficiency (nitrogen and iron in this study) in growing plants.

The final section of work in this block involves the study of growth substances. The student learns how to do a bioassay and does one. He studies the effects of indole acetic acid and gibberellic acid on growth and development, and, in addition, studies phototropism and geotropism. The bioassay involves

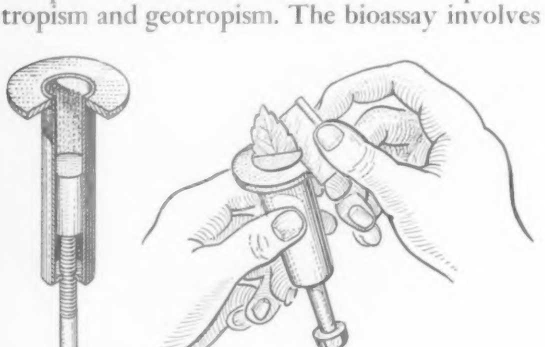


FIGURE 7. A hand microtome made of a machine bolt, nut, washer, short piece of pipe, and a wooden dowel. A cylinder of potato is cut with a cork borer to loosely fit the pipe. The plant material to be sectioned is embedded in the potato and slices made with a razor blade as indicated on the left.

FIGURE 8. Students in Mrs. Marjorie Behringer's Biology class, Alamo Heights High School, San Antonio, Texas, doing an experiment to study the effect of gibberellic acid on dwarf peas.

the setting up of known standards of IAA and then measuring straight growth of oat coleoptile sections placed in the standard solutions. The student then measures the amount of growth of coleoptiles placed in an unknown solution and compares with the standard curve to determine the equivalent IAA activity. To investigate the activity of gibberellic acid, Alaska peas (normal variety) and Little Marvel (dwarf variety) are used. Several plants of both are sprayed with a gibberellic acid solution, and other plants of both types are untreated and serve as controls. (Figure 8.) The tropism studies are modifications of the classic experiments of Charles Darwin, reported in *The Power of Movements in Plants*, published in 1880. They not only show directional growth in response to the stimuli of light and gravity but also indicate the importance of the growing point in these reactions.

In the section on growth substances, in particular, and throughout the block whenever it is considered appropriate, reference is made to the practical implications which have resulted from the basic type of research being studied or an extension of it. To quote from the block:

> Although the scientist is usually content to obtain new knowledge for its own sake and for the rewarding by-product of satisfying his own intelligent curiosity, it often turns out, sooner or later, that the new facts or understandings obtained may be put to immensely practical use for man's own benefit. Thus, the extent to which we can increase our knowledge of the organization

and mechanisms involved in growth and development will proportionately enable us to increase our ability to control these important processes. The knowledge obtained thus far, which has resulted in food-plant improvement, has been valuable in agriculture and in industry. Research has been valuable in improving other plants from which man obtains materials used in the production of drugs, vitamins, pharmaceuticals, and chemicals for disease control and planned growth. Who knows what the next discovery in the laboratory will make possible in the factory or in the field?

Biology In The News

Brother H. Charles, F.S.C.

DOCTORS IN THE DESERT, Allan M. McKelvie, M.D., *Saturday Evening Post*, July 22, 1961, pp. 13-15, 57-59.

Orthopedic surgeons donate a month of their time, pay their own expenses, and go to a foreign country to help the crippled. This article should inspire other real Americans to be generous too.

CRASH DIETS AND YOU, Jhan and June Robbins, *Cosmopolitan*, September 1961, pp. 50-53.

Millions of Americans go on crash diets every year. The evils of such practices are discussed and sensible procedures recommended.

TEN THOUSAND MEN WITH TROWELS, Hodding Carter, *Saturday Evening Post*, September 2, 1961, pp. 11-13, 70.

He men find that raising plants is satisfyingly creative and recreative. This hobby extends from tree planting to orchid culture.

THE POND, photographed by Alfred Eisenstaedt, *Life*, August 25, 1961, pp. 78-85.

Wonderful pictures for your bulletin board. Should inspire students to see beyond the obvious.

WHAT YOUR DOCTOR THINKS OF YOU, Ardis Whitman, *Redbook*, September 1961, pp. 44-45, 102-103.

Patient doctor relationships are extremely important. Faults on either side prevent effective treatment. This article could supply one side of a discussion and the students could provide the other.

BREAK YOUR BOY IN RIGHT, G. Howard Gillelan, *Outdoor Life*, September 1961, pp. 62-65, 76-80.

Contains much useful information about safety with guns.

THE GREAT WILDERNESS FIGHT, John Bird, *Saturday Evening Post*, July 8, 1961, pp. 30-31, 73-76.

All should be interested in the fight to preserve some areas in their natural state not only for biological study but also for the pleasure such areas afford. This report is good reading.

STRAIGHT TALK ON SEX AND GROWING UP, Ann Landers, *Life*, August 18, 1961, pp. 74-88.

The title indicates its content. Written for teenagers and their parents.

Junior Scientists Transactions

Another high school publication of student research is available from the Science Seminar, Redford Union High School, 17711 Kinloch Street, Detroit 40, Michigan. These projects were undertaken through the seminar approach initiated by the Joe Berg Foundation.

African Education

Kent State University, Kent, Ohio, and The Comparative Education Society are planning a field study program from June 16 to July 20, 1962, visiting major areas in Africa to study educational systems. Participants may continue on to Europe for other visiting. An alternate set of dates will be August 11 to September 20, 1962. Information about the program may be obtained from Dr. Gerald H. Read, Secretary-Treasurer, The Comparative Education Society, Kent State University, Kent, Ohio.

Gradwohl Memorial Scholarship

Applications are now open for the third annual Dr. Gradwohl Memorial Scholarship for $1,000 full tuition which will be awarded early next year for the study of medical laboratory technology. Information may be secured at the school office, 3514 Lucas Avenue, St. Louis 3, Missouri.

An Ancient Method of Fish Mounting

GORDON CHAN
Sir Francis Drake High School, San Anselmo, California

The method of fish mounting described in this article is really a method of salt embalming. Some of my colleagues have described this method as a way of turning a fish into a mummy. The procedure set forth has been tested and shown to be extremely simple and easy to follow.

The author is not the first person to use this method. The ancient Egyptians embalmed almost everything that crawled or walked on legs. Their method of making mummies involved the use of spices and oils. At the time that the Egyptians were in their prime and making mummies, the Chinese were practicing an art of embalming fish by salting them in order to preserve the fish for later consumption. So, in truth, this method of fish embalming began with the ancient Chinese, about 3,000 years ago. In fact, it has been reported by some Chinese fish embalmers in San Francisco that some of their salted fish are hundreds of years old and are still palatable! Today, the Orientals are still consuming salted fish as a part of their daily diet. Their cookery method of steaming the salted fish with rice produces a dish which is considered a delicacy.

There are several practical reasons for such mummy displays. The saving of time, especially for a teacher, and the little equipment needed, are the greatest advantages. Total labor hours in mounting a three-foot fish would be about one hour. As the technique is explained, one can see that little equipment is needed for such preparations. Another advantage is that there is very little, but some, shrinkage of the fish due to the loss of water. The salt toughens the cellular tissues despite the great loss of water. Finally, the method has the advantage of retaining much of the external anatomical details of the fish, such as the scale, some color, and fins. Also, because of its rigidity, the fish, after drying, can be handled by students without too much fear of breaking off any appendages.

Figure 1. In formaldehyde.

Figure 2. Salting.

The great disadvantage of the salt-embalming methods is that the fish loses some proportions of its original size, especially of the eyes. However, one can utilize false eyes for a better looking model. Also, the skin, in some degree, will be shrunken and folded. If satisfaction is not obtained by this salt preparation and if the worker has much time to devote towards a better looking model, I would recommend two finely illustrated books on taxidermy and plastic model preparation of fish.[1]

I have had the greatest success in the salt preparation of the cartilaginous fish, such as sharks and rays. One of the easiest fish to prepare is the flatfish. The flatfish today is

[1]Mayer, John W., *Practical Taxidermy*, The Ronald Press, New York. Pond, Gordon G., *Science Materials*, Wm. C. Brown Co., Dubuque, Iowa.

Figure 3. Salt bag.

most common preparation of the Chinese fish merchants. Other bony fish can also be salted with satisfactory results. One should keep in mind that the larger fish make better looking models. Very small fish have too much shrinkage for a lifelike display. The following steps utilize a leopard shark, *Triakis semifasciata*, as the example in demonstrating this technique.

1. The initial step when one obtains a fish is to record the data on its external measurements, source or location where the fish was obtained, date, and collector. Proceed then to make a ventral incision in the fish, remove internal organs, and then immerse fish in 8-10% formaldehyde solution for at least one week (Fig. 1). The larger the fish, the longer the immersion in formaldehyde. The formaldehyde will help preserve the fish by stiffening the tissues. One may also measure and gut the fish after preservation in formaldehyde.

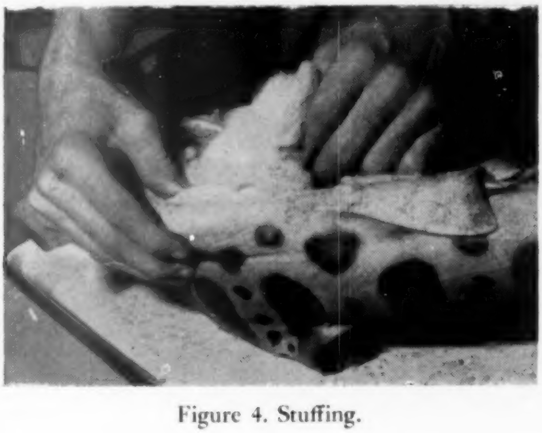


Figure 4. Stuffing.

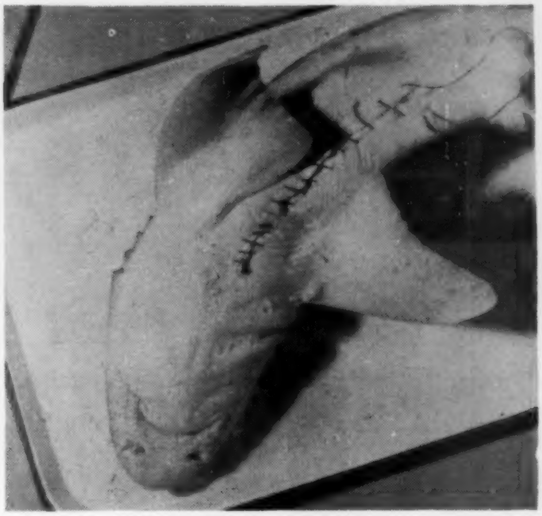


Figure 5. Sewing.

If one cannot obtain a fish through local markets or water habitats, satisfactory fishes can be purchased through many biological supply houses.

2. Remove the fish from the formaldehyde and rinse it in running water. Then rub salt into the fish with your hands (Fig. 2). Rock salt is generally preferred. In rubbing the salt into the flesh with your hands, externally and internally, be very careful of the various

Figure 6. Taxidermy powder.

Figure 7. Mounting-drying.

spines and scales. A brush may be substituted for your hand. Next, place the fish in a plastic bag surrounded by the rock salt. Allow several days for the salt to penetrate and toughen the tissues—the longer, the better (Fig. 3).

3. Remove the salted fish from the bag and save the rock salt by placing it in a glass sealed jar for future fishes. Rub the insides of the fish with taxidermy powder. Powdered borax or sodium arsenite may be used. The former powder is the safest while the latter should be labeled POISON and kept covered in a glass container. Stuff (Fig. 4) the internal cavity with papier-mache or nonabsorbent cotton. Then sew up the ventral incision (Fig. 5).

4. Tie the fish on a board, using smaller pieces of wood and clamps to keep the body and fins straight (Figs. 6 and 7). Rub the

Figure 8. Finished product.

Figure 9. Other salted fish.

taxidermy powder on while mounting. The various preservatives of formaldehyde, salt, and taxidermy powder will permanently preserve the flesh from insect, fungus, and other decays.

5. Let the fish dry in sunlight or in your room. This leopard shark, held by the author, dried inside the classroom in two weeks (Fig. 8). After drying, brush off the excess powder and apply a coat of plastic spray. Label your finished product.

The last photo (Fig. 9) shows but a few of the fish displayed in my classroom. Two flatfish can be seen at the top of the photograph. May I just point out that such preparations will greatly enhance your biology program.

Encouraging Writing

The Spring Branch Independent School District, Houston, Texas, has voted to give a scholarship of $150 for an article published by a teacher in the system in a state periodical or $250 for an article published in a national journal. This money may be used by the teacher for travel or school expense. This is a real method by which local school districts can give fitting recognition to professional writing on the part of teachers in the system. Certainly, the teachers throughout the country will benefit, and a real encouragement will be given to local teachers for such activity.

Physiological Demonstration of the Quahog Heart: Apparatus and Techniques

JOHN D. DAVIS, *University of New Hampshire, Durham*

During the early nineteen-forties it was discovered that the heart of *Venus mercenaria* was a reliable testing device for acetylcholine (1). Subsequently, the organ has been used in various bio-assay techniques. This paper will consider certain related procedures that are adaptable to secondary school biology courses. The discussion is centered around three topics: description of apparatus, technique, and suggestions for further reading.

The basic instrument is a kymograph, a device with a revolving drum for recording any sort of pulsation. Most kymographs offer a choice of speeds. In this case, one of the slower speeds is desirable.

A timing device is necessary to indicate the duration of any part of the record. As electrical timers are costly and tuning forks too rapid for this work, an inexpensive timer can be constructed from an alarm clock and doorbell. The ordinary alarm clock has a counterspring which expands and contracts approximately twice per second. This spring will withstand the friction of a bare wire without loss of motion, allowing attachment of an insulated wire with the bare end contacting the spring every half-second. The wiring of the clock is shown in Figure 3.

The timing stylus can be constructed from a doorbell, with the bell and outer portion of the striker removed. The marking stylus, a piece of photographic film cut to a point, is attached to the remainder of the striker. The circuit-breaker of the bell is bypassed, causing the current through the electromagnets to be continuous. Tape is wound about the circuit-breaker post to prevent excessive vibration of the stylus. See Figure 2. A transformer or dry cell provides the current. Whenever contact is made on the counterspring, the marking stylus will trace a pattern on the drum.

The marking stylus for recording the heartbeat can be constructed from two soda straws suspended on a steel wire. The two straws are joined by gluing portions of split straws on adjacent ends. The length of the lever, including writing point, should be about 34 cm., placing the wire fulcrum about 25 cm. from the point. The wire is mounted in a clamp attached to a ring stand. The plane in which the lever moves should be exactly parallel to the surface of the drum. If not, the stylus may lose contact with the drum during extremities of pulsation. A thread, with a bent pin hook on one end, is attached to the other end of the lever.

The kymograph drum is prepared by covering it with glossy paper and rotating it above a benzene flame until carbon covers the paper. Upon completion of the experiment, the record is made permanent by dipping the paper in shellac and allowing to dry.

The animal is mounted in a pan deep enough for complete immersion. The pan should be completely lined with aluminum foil, because adrenalin chloride quickly decomposes upon contact with oxidizing agents, iron salts, and alkalies. Glass or plastic will eliminate the need for foil. The foil-covered pan is mounted in a larger pan having an overflow tube. The overflow is below the lip of the specimen pan. Thus, sea water can run into the foil-covered pan and over into the larger pan which will fill and then empty through the overflow. Therefore, drug solutions can be introduced and flushed out without disturbing the quahog. A funnel and thermometer, mounted on a ringstand, are brought in contact with the sea water in the specimen pan.

The quahog, *Venus mercenaria (Mercenaria mercenaria)*, is the common hardshelled clam found along the east coast of the United States. *Venus* can be dug in many areas along the coast or can be purchased from local fish markets. Otherwise, the best source is a biological supply house. Other related species can be substituted but may be less reliable.

Quahogs are dependable as experimental animals for as long as two weeks after being dug. They may be stored dry in temperatures of 5°C to 10°C. If kept in tanks of aerated sea water, a temperature of 15°C to 18°C

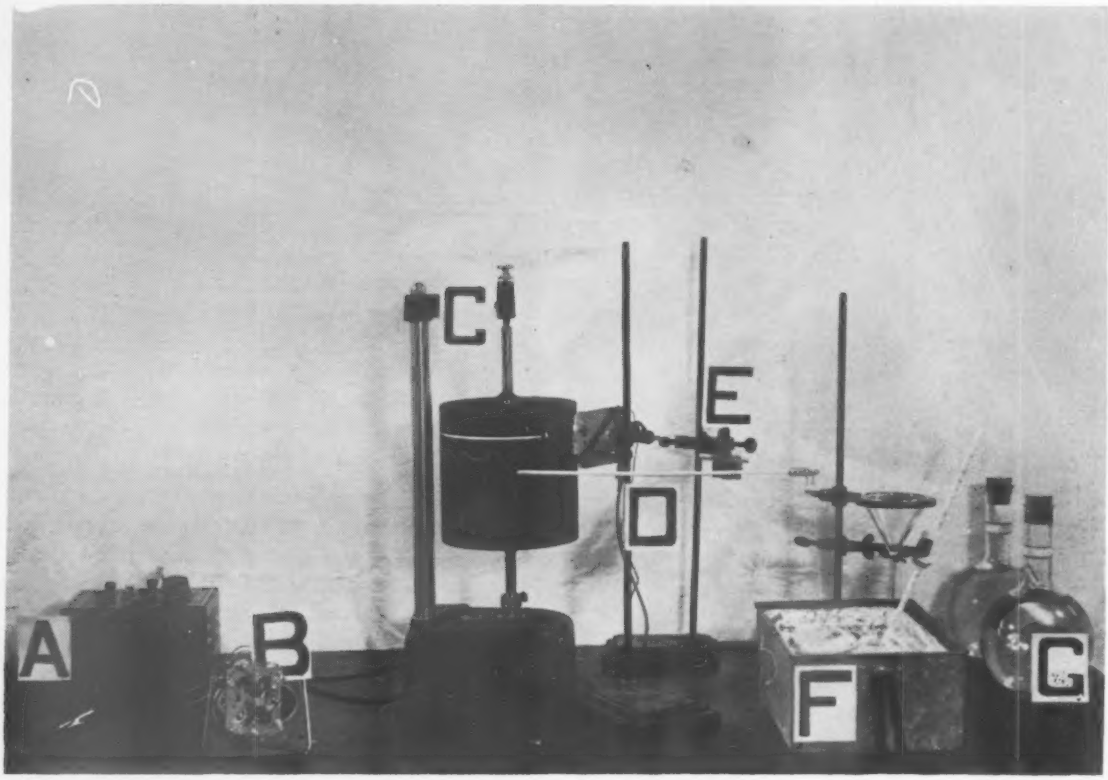


Figure 1. Complete apparatus for demonstration of quahog heart. (A) Transformer producing current to operate timer. (B) Modified alarm clock; circuit-breaker produces half-second impulse. (C) Kymograph with smoked drum. (D) Doorbell modified to mark time record on drum. (E) Writing lever (soda straws) supported by clamp and ring stand. (F) Collecting pan and overflow. Inside is foil-covered pan containing quahog. (G) Drug solutions.

is preferable (3). If sea water is not available, the following can be substituted: 30 gm. NaCl, 0.9 gm. KCl, 1.1 gm. $CaCl_2$, 3.5 gm. $MgSO_4 \cdot 3H_2O$ in one liter of distilled water with a phosphate or bicarbonate buffer with a pH of 7.0 to 7.5 (3).

During experimentation it is not necessary to aerate the water, because oxygen requirements of the molluscan heart are low (2). If it were desired to continue experimentation for several days, aeration and water-change would be necessary. All sea water and drug solutions should be cooled to about 12°C before use.

Excellent results can be achieved with adrenalin chloride and acetylcholine chloride. Adrenalin chloride, initially in 10^{-3} solution (or 1:1000) should be diluted to 10^{-5} (1:100,000) solution and prepared in one-liter quantities. Acetylcholine chloride can be acquired in 100 mg. ampuls and prepared in 10^{-4} solution also in one liter quantities. Both solutions should be refrigerated until use.

Prepare the *Venus* by placing it on a hard, sturdy surface with the right valve down, for example. Then break the left valve with a hammer. The parts of the shell are separated enough to permit cutting of the anterior and posterior adductor muscles. Then, the entire broken valve is separated from the mantle and removed. Next, the left mantle is removed. The pericardial cavity can be located dorsally in the area between the umbo and the posterior adductor muscle. Careful lifting and tearing with forceps of the tissue in this region eventually will bring the cavity into view. The slowly pulsating tube, passing anterior to posterior through the cavity, is the heart. Careful observation is necessary to determine the full extent of the heart. The area around the heart and cavity should be cleared of any obstructions that would impair heart pulsations, and the animal immediately immersed in salt water. Place the

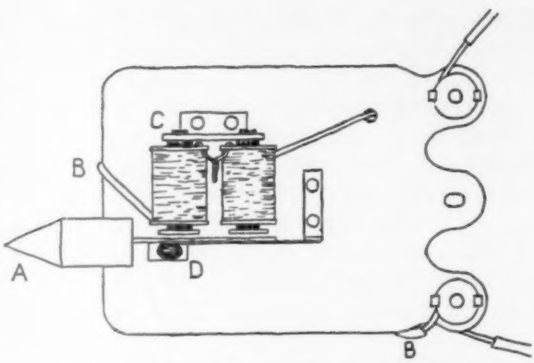


Figure 2. Timing stylus made from doorbell. (A) Marking stylus made from photographic film and attached to remainder of striker. (B) Wire by-passing original circuit-breaker. Permits current to be continuous. (C) Electromagnets. (D) Circuit-breaker post (now disconnected) wound with tape to prevent excessive vibration by stylus. The wire from one post leads to the clock, the other to the transformer.

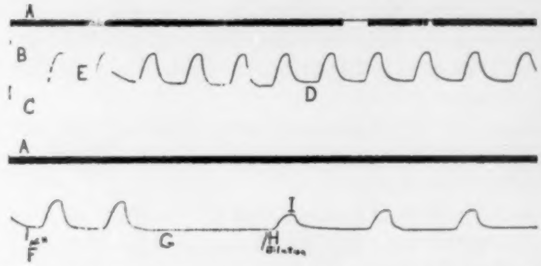


Figure 4. Portion of a typical kymograph record. (A) Time record (half-second intervals). (B) Normal beat. (C) Addition of adrenalin chloride (10^{-8}). (D) Slow increase in tonus. (E) Mechanical trouble—contact on the drum insufficient to leave record. (F) Addition of acetylcholine chloride (10^{-4}). Lower record separate—made by raising the drum. (G) Suppression of heartbeat. (H) Dilution with sea water (8cc/second). (I) Reappearance of modified heartbeat. Picture of kymograph record made by placing kymograph paper, record side down, on photographic paper and exposing to 60W lamp for 15 seconds at 24 inches.

mollusk in the pan so the heart is located directly below the end of the writing lever, and insert the hook into the ventricular heart tissue. The time stylus and writing point can then be placed against the smoked drum and the kymograph set in operation. Figure 4 represents a typical record made by this technique.

Addition and removal of various drug solutions will produce different records. Nicotine is one which exhibits results similar to acetylcholine. Treatment with eserine (10^{-4}) for 15-30 minutes before addition of acetylcholine will increase the magnitude of the inhibitory effects, but recovery will be longer. It should be noted that there is considerable seasonal variation in the drug sensitivity of *V. mercenaria.* Acetylcholine sensitivity to solutions of 10^{-12} has been recorded during the spring (1). The heartbeat is often irregular during August and September.

The amazing durability of the *Venus* heart, an important factor in choosing animals for physiological demonstrations, is well-displayed by this technique.

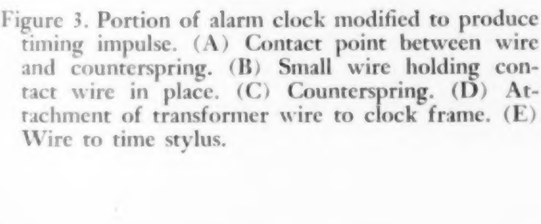


Figure 3. Portion of alarm clock modified to produce timing impulse. (A) Contact point between wire and counterspring. (B) Small wire holding contact wire in place. (C) Counterspring. (D) Attachment of transformer wire to clock frame. (E) Wire to time stylus.

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Bard Award

Dr. Detlev Bronk, President of the Rockefeller Institute for Medical Research, was given the first Bard Award at the Bard College commencement. It is given to an outstanding scientist.

AAAS Cooperative Committee Meeting

The University of Minnesota was the site of the April 21-22, 1961, meetings. Dr. Thornton Page, Committee Chairman and the representative to the Committee from the American Astronomical Society, was in charge.

AAAS has established a new position entitled: Director, Studies on Public Understanding of Science. Since this area of understanding has long been neglected, it seems appropriate for an organization such as AAAS to undertake studies in its behalf. The membership of NABT is therefore alerted to this development. The long range impacts of such studies can be most helpful to the further development of the sciences in the United States. The Carnegie Corporation in April renewed its grant to AAAS for a continuation of its study with the National Association of State Directors of Teacher Education and Certification. The grant is for a continuation of the "Teacher Preparation–Certification Study." AAAS will continue publication of "Science Education News." The AAAS Study on the Use of Special Teachers is now in the second year, and also during this year AAAS has been supporting "Studies in Teacher Education" at nine different colleges. Reports on these programs and others will be given at the Denver meeting. AAAS has again been responsible for providing assistance with the operation of the NSF Fellowship Program. This year, 325 fellowships were given to science teachers under this program. Some 1800 made application. AAAS also has assumed responsibility for bringing foreign lecturers to NSF Summer Institutes. During 1961, some 18 foreign lecturers will visit some 150 Summer Institutes.

The Cooperative Committee received a preliminary report of the feasibility study on elementary and junior-high school science. The recommendations of the Steering Committee have appeared in *Science*.

Reports on mathematics education programs included mention of eight Regional Orientation Conferences in Mathematics held for selected secondary school administrators and supervisors. These were sponsored by the National Council of Teachers of Mathematics and were supported by a grant from NSF. A second report of the Committee on the Undergraduate Program in Mathematics (CUMP) of The Mathematical Association of America was given. CUMP now has four panels. They are: 1. Teacher Training, 2. Mathematics for Physical Science and Engineering, 3. Mathematics for the Biological, Social, and Management Sciences, and 4. Pre-Graduate Training.

It was suggested that the Cooperative Committee consider the establishment of a mechanism under which abstracts of articles on science and mathematics education would be exchanged among journals devoted to these two areas. A member of the Cooperative Committee will attempt to learn about the feasibility of bringing together editors of mathematics education and science education journals for the purpose of studying the exchange of abstracts idea.

Several subcommittee reports were given. The Chairman of the Subcommittee on Science Teaching Laboratories is undertaking a survey of existing science teaching laboratories. A report will be available in the fall of 1961. The Subcommittee on Science Curriculum Programs reported on the national curriculum revision programs now in progress. Programs in biology, chemistry, physics, and conservation were described. It was suggested that this Subcommittee study programs in general science and also study preservice and inservice programs which may be necessary for preparing teachers to handle the new curriculums.

A brief report by the Chairman of the Subcommittee on Motion Pictures considered suggestions for: evaluation of films, and the establishing of a traveling science film library. Further reports from this Subcommittee will be given in the Fall, 1961, meeting of the Cooperative Committee. The Subcommittee on the Congress on Education will continue its study of the feasibility of establishing such a Congress. The Subcommittee on Professional Education Requirements for science and mathematics teachers will prepare a report to be circulated to several organizations of professional educators prior to its release by the Committee. The Subcommittees will continue their work through the coming year.

It was proposed that members of the Cooperative Committee be appointed by their sponsoring societies for a period of three years.

H. Seymour Fowler
NABT Representative

Experimenting With Hydroponics

B. JOHN SYROCKI, *College of Education, State University of New York, Brockport*

Growing plants in nutrient solutions, or hydroponics, is a most rewarding experience. Pupils enjoy experimenting with plant growth and are able to demonstrate vividly the specific requirements of plants for sustained growth and food production. Within 47 days some pea seeds can be grown to produce flowers, and pods at least two inches long. By using specific salts to prepare the fertilizing salt solutions and solutions containing the trace elements, the amount of the various chemicals in the formula may be varied according to purposes of experimentation.

The Water-Culture Method

The method discussed in this paper concerns the growth of plants in nutrient solutions. Some method is devised whereby plants are suspended over the solutions. The plant roots grow into the solution, and the solution is aerated and replenished with salts.

Plant Solutions

The nutrient solutions consist of fertilizing salts and trace elements. The formulae, with only slight modification, are the ones recommended in Bulletin 636 of the New Jersey Agricultural Station.

Fertilizing Solution I. Prepare one gallon of solution by dissolving each salt separately in about a pint of lukewarm water. One-pint canning jars are very handy. Pulverize large crystals of salts into a powder form before measuring out the salt. Crush the crystals with a mortar and pestle or simply with the back side of a spoon. Pour the solutions of each salt into a gallon jug and add water to make one gallon. Use the chemicals and quantities as follows:

Solution I

Fertilizing Salts	*Teaspoonful/Gal.*
Mono-potassium phosphate KH_2PO_4	¼
Calcium nitrate $Ca(NO_3) \bullet 4H_2O$	1¼
Magnesium sulfate $MgSO_4 \bullet 7H_2O$	½
Ammonium sulfate $(NH_4)_2 \bullet 2SO_4$	⅛

Solution II

**Trace Elements* Stock Solution A	*Amount*
Boric acid H_3BO_3	¼ tsp.
Manganese sulfate $MnSO_4 \bullet 7H_2O$	¼ tsp.
Zinc sulfate $ZnSO_4 \bullet 7H_2O$	¼ tsp.
Copper sulfate $CuSO_4 \bullet 5H_2O$	Pinch
**Trace Elements* Solution B	*Amount*
Ferric chloride $FeCl_3$	¼ tsp.

*Add the following amounts of the trace elements (Stock A and B) to Solution I just before using:

Solution A	½ tsp /gallon
Solution B	4 tsps/gallon

Containers

In suspending plants over nutrient solutions, it is necessary to use some means of supporting plants as they continue to grow.

Making Wire Containers. Wire baskets are helpful in helping to keep plants in upright position during growth. Obtain a strip of ¼ inch mesh hardware cloth 1 foot long and 3 feet wide. This is sufficient to make 8 small baskets. Construct each basket as follows:

Cut a strip of the screening (hardware cloth) 5 inches wide and 10 inches long. Along one side of the long side of the screening, cut so that the edge is without the sharp points of wire as shown in "A" in Figure 1. Note that the other long side is cut with shears so that there remain projecting points as seen in "B" of Figure 1.

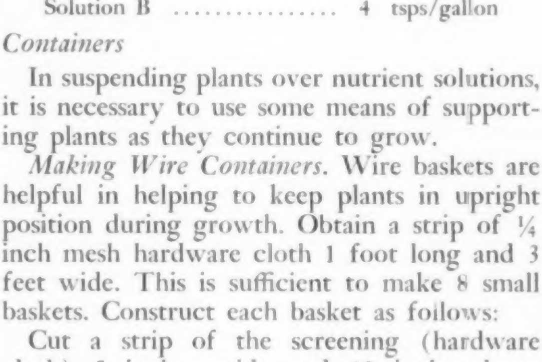

Figure 1. Preparing a wire basket for hydroponics.

Scribe a circle on a firm piece of thin cardboard and cut out the circle. Use a radius of 1 inch for baskets to be put into narrow mouthed quart jars, and a 1½ inch radius for baskets to be put into wide-mouthed canning jars. Use the cardboard as a guide to cut out a circle of wire screening as seen in "C" of

Figure 1. As demonstrated in Figure 1, roll the rectangular piece of screening so that the round piece of wire can be inserted, edge to edge, over the points protruding along the long edge. Put these points through the outer edge of the round piece of screening and bend over the points with a screwdriver as seen in "D" of Figure 1. This fastens the edges together. Continue to do so until you have formed the basket.

Where the points along edge "F" in Figure 1 unite with edge "E," bend over the points to fasten edge "E" to "F." Figure 2 shows edges "E" and "F" united.

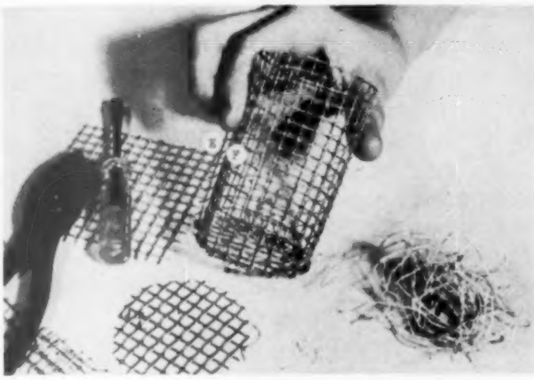

Figure 2. The completed wire basket.

The wire basket is now completed. With the edge of pliers, tap the bottom edges firmly to be sure that no sharp points of the screening protrude in such a way as to cause injury during handling.

A decided advantage in using this kind of wire basket is that as water is consumed and evaporated, the basket can be easily lowered into the solution to keep the roots submerged. Note that a "lollipop" stick about 5 inches long is pushed through both sides of the basket. The stick supports the basket on the rim of the wide-mouthed jar. The stick is removable and can be reset to raise or lower the basket in the jar.

A Plywood Support. Drill a hole ⅜ of an inch in the center of a piece of plywood ¼ of an inch thick and 3 inches square. The roots of a small *Coleus* plant are pushed through the hole. The plant will actually rest on the first set of leaves or on actual portions of stems should you use a geranium plant. Even when the *Coleus* plants grew 10 inches high, this type of support served adequately during the period of experimentation.

Figure 3. Showing how the wire basket is raised or lowered into solutions.

Aluminum Pie-Tins. Fast growing plants of low habit, such as radish seeds, can be grown easily to a height of 3 inches during experimental study. The very early formation of radishes can be demonstrated. This kind of container is seen in Figure 5.

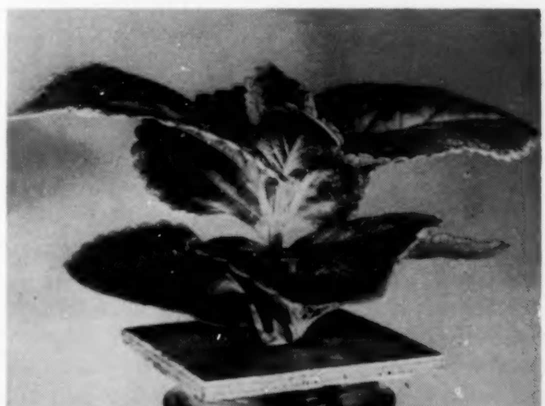

Figure 4. A wooden support for *Coleus* plants.

Figure 5. Glass and metal containers for growing plants in nutrient solutions.

To use a pie-tin for growing radishes, a base and cover of paper towels is prepared. Five paper towels are superimposed over each other and stapled together a few times. Prepare another group of towels in the same manner. Put the aluminum tin, bottom side down, over the toweling and trace along the bottom edge. Cut the paper to fit in the bottom of the tin. You will now have the base and cover. Restaple the cover, especially around the edges, so that the papers will hold well to each other when the cover is removed to inspect germination.

Put the base into the pie-tin, soak the toweling, and sprinkle radish seeds over the base. Put the cover over the seeds and wet the cover generously. When seeds germinate and show roots and stems, remove the cover and put the container in the light. Keep the paper base watered at all times. Plant roots will embed in the paper toweling and will be able to anchor the growing plant. When plants are 1 inch high, add the complete nutrient solution in place of water to promote plant growth.

Glass Containers. Olive jars and drinking glasses may be used to grow plants in chemical solutions. Line the inside of the containers with blotting paper as seen in Figure 5. Staple the ends of the blotter together so that the blotter fits snugly against the glass. Pull the blotter away gently from the upper portion of the glass and insert a pea, bean, or corn seed. Place 4 or 5 seeds around the glass container in the same manner. Fill the jar half-full with a nutrient solution.

Aeration

In the water-culture method, as oxygen is used by the plant, more oxygen must be put into the nutrient solution. This is done by using a commercial air pump, such as the type used in aerating aquaria. Note that the baskets may be easily lifted to allow the air hose to drop into the solution.

When plants have grown to a height of 2 or more inches, aerate the plants 2 times per week for 3 to 4 minutes each time. Prior to this growth, aerate once a week for 1 to 2 minutes. Should a porcelain aerating tip be unavailable, pinch off the tip of the aerating tube with a common pin, or staple the tip lengthwise to provide smaller bubbles.

Lighting

Plants can be grown in any part of the classroom provided that adequate lighting is maintained. A fluorescent light source of two 15 watt tube-lights in addition to the room light was adequate to sustain growth. Your lights may be suspended over your plants on 2 wooden supports as seen in Figure 6. With the use of the main light source directly over the plants, much of the bending of plants toward window light will be eliminated and the plants will remain erect.

Figure 6. Lighting and storage facilities.

Experiments on Plant Growth

Under proper conditions, plants will grow well in nutrient solutions. Proper nourishment will usually result in vigorous growth of leaves, stems, and roots. When certain chemicals are missing from the plant's normal diet, the plant is visibly affected in one or more ways. By varying the plant's diet, we can determine the ways in which certain chemicals benefit plant growth. Since the chemical formulae are prepared by the experimenter, it is convenient to delete specific components of the nutrient solution. In experimenting with plants, it will be necessary to maintain *control plants*. This is accomplished by growing plants similar to those undergoing experimentation, only in the instance of the control plants the diet is fully adequate. The experimental plants may be compared with the controls, and conclusions reached with a greater degree of assurance.

Selecting the Plants

Plants from Seeds. Pea seeds, Morses's Progress No. 9 (Dwarf) sold by the Ferry-Morse Seed Company, were used satisfactorily. Five seeds were placed into excelsior in a wire basket, and the basket was then lowered in order to wet the excelsior. The wet excelsior will keep the pea seeds adequately moisturized to promote germination. When the pea plants are about 2 inches high, remove the 3 plants showing the least vigorous growth. As the plant stem continues to grow, pack more excelsior around the stem to give it more support.

When grown in a proper nutrient solution, these pea seeds will usually flower in 33 days and form pods about 2 inches long in 47 days. String beans, Tenderbest (Bush) distributed by the Ferry-Morse Company, were also used most successfully. String beans will usually flower in 42 days.

Greenhouse Plants. The green and red variegated varieties of *Coleus* plants were used in experimentation. Select 2 or 3 plants of each variety of *Coleus* which are no more than 2 inches high and appear alike in vigor and number of leaves. Use 2 plants for the experimentation and one for the control plant.

Remove the plants from their containers and immerse the roots and soil in water. Continue to agitate the roots gently until soil particles are loosened from the roots. Remove the plant from the water and push the root system through the hole in the wooden support. Immerse the roots in the nutrient solution.

Cuttings. The geranium plant is useful for starting new plants. Remove a portion of the stem of a geranium plant allowing two small leaves to remain on the stem. Put the stem through the holes in a wooden support and immerse the cut end in a nutrient solution.

Varying the Nutrient Solutions

Lacking Nitrates. Prepare the basic solution in the prescribed manner, except omit the calcium nitrate in the fertilizing salt solution. Add the trace elements and immerse the roots of seedlings in this solution.

Bean plants and *Coleus* plants grown in solutions lacking in nitrates are definitely smaller and much less vigorous looking. In Figure 7, Plant "A" was grown in a complete nutrient solution, whereas Plant "B" was grown in a solution lacking calcium nitrate.

Figure 7. Bean plants grown with and without calcium nitrate.

Lacking Trace Elements. The fertilizing solution is prepared in the usual way. Trace elements are not added to the salt solution. It is possible to delete only the iron in Solution B, or omit any of the elements in Solution A, such as boron. In working with the *Coleus* plants, all trace elements were omitted from the nutrient solution.

In Figure 8, showing the *Coleus* plants used in the experiment, drastic differences were

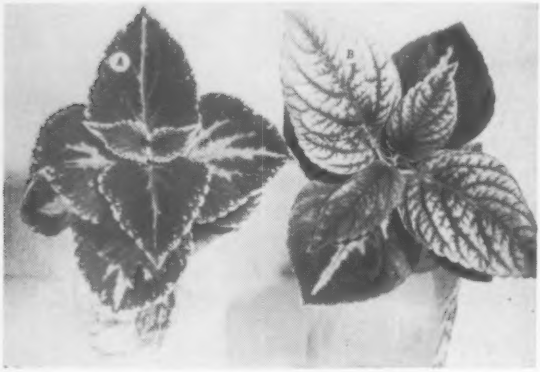

Figure 8. Red *Coleus* plants grown with and without trace elements.

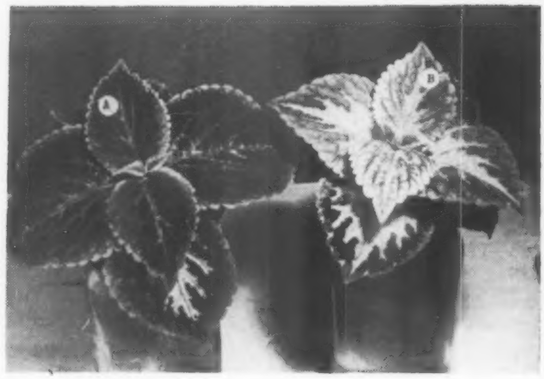

Figure 9. Green *Coleus* plants grown with and without trace elements.

noted in leaf coloration. Grown in complete solutions, the *Coleus* Plant "A" showed bright red colors in the leaf proper and a green leaf margin. Without trace elements, Plant "B" showed lack of red in the leaves, and leaves appeared brown with no green leaf margins.

In Figure 9, green *Coleus* Plant "A" was grown in the complete nutrient solution. Plant "A" retained its dark green color throughout the leaf and some red along the midrib. The leaf margin remained bright green. In green Plant "B" which was grown without trace elements, the leaves became a very pale green. All new leaves showed slight traces of green.

Microbiology in Your Future

The American Society for Microbiology has just issued an attractive new career and guidance booklet in microbiology. It should prove quite appealing to the high school student reader. The ASM sponsored the popular June, 1960, issue of the ABT. Single copies of the new publication may be obtained free from the Executive Secretary, Mr. Ray Sarber, ASM, 19875 Mack Avenue, Detroit 36, Michigan. More than one copy are 10 cents per copy.

AAAS Botany Symposium

Section G (Botany) will present a special program at the AAAS meetings in Denver, Wednesday, December 27. The subject of the symposium will be, "Plant Biology Today: Advances and Challenges." Professor Harriet Creighton of Wellesley College will preside. Speakers will include Anton Lang, California Institute of Technology, on "The Control of Plant Growth by Environment"; James Bonner, California Institute of Technology; William A. Jensen, University of California (Berkeley), on "The Problem of Cell Development"; Beatrice M. Sweeney, Scripps Institute of Oceanography, on "Biological Clocks in Plants"; Lawrence Bogorad, University of Chicago, on "Photosynthesis"; and Frank B. Salisbury, Colorado State University, on "Translocation: The Movement of Dissolved Substances within Plants."

Paragraphs To Learn By

John M. Youngpeter, Portage, Ohio, has indicated that he would be willing to edit a column in which teachers and other interested persons might submit brief paragraphs which would present teaching ideas that are not sufficiently long for an entire journal article. Such teaching hints and ideas should be sent to John at the above address, and, if there is sufficient interest, such a column will be published shortly on a regular basis.

Lab Equipment

Copies of the report, "Suggested Built-in Instruments and Equipment for Laboratory Furniture—Including Certain Specific Finish Requirements," may be obtained without charge from: Laboratory Equipment Section, Scientific Apparatus Makers Association, 20 N. Wacker Drive, Chicago 6, Illinois.

Nominations for 1962 Officers

The following nominations are presented by the Nominating Committee appointed by President Paul Webster. The members of the Committee are: Frances Gourley, Chairman; William Foil; Paul Klinge; Robert L. Smith; and Howard Weaver. Ballots will be mailed by the Secretary-Treasurer.

Regional Directors in Regions I, IV, V, VII, VIII, and IX will be elected this year. Regional Directors in Regions II, III, and VI were elected last year and will serve another year of their two-year terms.

Duties of the officers are briefly: President-Elect, prepare for presidential duties and arrange program for AAAS meeting; First Vice-President, substitute for the President and arrange program for AIBS meeting; Second Vice-President, substitute for First Vice-President and in charge of affiliates; Third Vice-President, substitute for Second Vice-President and in charge of membership promotion; Secretary-Treasurer, keep records, disburse and receive funds and fees; Recording Secretary, keep official Board minutes and have stationery printed; and Regional Directors, represent Region on Board, promote regional NABT activities, initiate teacher award programs, and arrange for regional meetings.

Candidate for President-Elect

Phillip R. Fordyce

Present Position: Biology teacher, Oak Park-River Forest High School, Oak Park, Illinois.

Degrees: B.S. and M.S., Butler University. Additional thirty graduate hours in biology.

Experience: Science teacher in junior high school one year. High school biology teacher ten years. Participant in the establishment of the national Advanced Placement Program in biology. Active in study of gifted students in science. Has sponsored Science Talent Search and Science Fair winners. Has had six students selected for Jackson Laboratory's Precollegiate Program. Recipient of three NSF Summer Institute grants and a three-summer AAAS Fellowship. Served as Assistant Director for Indiana University High School Science Student Institute two years. Awarded first annual Science Teacher Award by Indiana Section of American Chemical Society; Armed Forces Chemical Association's candidate from Mid-West Region for National Science Teacher Award. Sponsor of an active 250-member Biology Club. Member of the AIBS Education Committee. Guest lecturer, AIBS Film Series. Participant in both of the BSCS Writing Conferences. BSCS Center Leader for Chicago area Blue Version Evaluation Center. High School consultant for Microbiology Unit of AIBS Film Series and forthcoming Careers Booklet. Recipient of an NSTA STAR '60 Award. Member of Chicago Heart Association's Committee on Recruitment to the Biological Sciences.

NABT Activities: Local chairman, 1957 AAAS, 1958 AIBS, and 1959 AAAS meetings. First Vice-President, 1960. Past Membership Co-Chairman for Indiana. NABT representative, National Council of the National Society for Medical Research. Member, Liaison Committee.

Organization Membership and Activities: Member, NSTA, CASMT, NIABT, Illinois Junior Academy of Science, and Phi Delta Kappa. Panelist, NSF. Presented papers at American Society of Zoologists, NABT, NSTA, and CASMT meetings.

Publications: Articles in *ABT*, *The Science Teacher*, and *School Science and Mathematics.*

Candidate for President-Elect

H. Seymour Fowler

Present Position: Associate Professor of Nature and Science Education and Director of the Pennsylvania Conservation Laboratory, The Pennsylvania State University, University Park, Pennsylvania.

Degrees: B.S., M.S., Ph.D., Cornell University.

Experience: High school science teacher in schools of central New York State. Assistant Professor of Science Education, Southern Oregon College. Assistant Professor of Biology and Director of the Iowa Teachers Conservation Camp, Iowa State Teachers College. Coordinator of the Pennsylvania State University Center of the AAAS STIP program. Director of two NSF Institutes at Penn State. Instructor in NSF Institutes at the University of Rochester, The Virginia State College, and the University of Texas.

NABT Activities: First Vice-President (1959). Local Arrangements Chairman, AIBS 1959. Membership Chairman of the Midwest Region and the Middle Atlantic Region. National Membership Chairman.

Iowa Chairman for Conservation Project. Chairman of Professional Problems Committee. NABT representative to AAAS Cooperative Committee. Member, Liaison Committee, Institutes Committee.

Organization Membership and Activities: Vice-President ANSS (1958). Chairman and Editor of the Science Materials Review Committee of NSTA. Iowa Academy of Science (Fellow). AAAS Fellow. Member, AIBS, Phi Delta Kappa, Beta Beta Beta, and Phi Kappa Phi. Produced TV programs, "Let's Explore Science," for WOI-TV, Ames, Iowa. Science Books Consultant for the American Library Association. Member, Conservation Education Committee of the Soil Conservation Society of America.

Publications: Articles in *School Science and Mathematics, ABT, Nature, Iowa Soil and Water, Soil Conservation, Journal of Educational Research, Midland Schools, Science Education.* Report, Science Materials and Review Committee in each issue of *The Science Teacher.* Monograph in preparation for *Library of Applied Educational Research,* "Science Teaching Practices and Trends in the American High School."

Candidate for First Vice-President

Addison Earl Lee

Present Position: Professor of Science Education and Director, Science Education Center, University of Texas, Austin.

Degrees: B.S., Stephen F. Austin Teachers College, Nacogdoches, Texas. M.S., Texas A. & M. College, College Station. Ph.D., The University of Texas.

Experience: Associate Professor of Botany, The University of Texas. Visiting Professor, The University of Virginia. Biology teacher and chairman of the biological science department, Austin High School, Austin, Texas. Principal Engineering Aide, U. S. Public Health Service. Biology teacher to high school principal, Douglas High School, Douglas, Texas. Lab Technician, Texas State Health Department.

NABT Activities: Speeches at three annual NABT meetings.

Organization Membership and Activities: Member, AAAS, Botanical Society of America, NSTA, Sigma Xi, Torrey Botanical Club, AIBS. Chairman, Committee on Innovation in Laboratory Instruction, BSCS. Fellow, Texas Academy of Science. Director, Texas Academy of Science Visiting Scientist Program.

Publications: Coauthor, "Biology, A Worktest in High School Biology," The Steck Company, Austin, Texas; "Laboratory Studies in Biology," Harper and Brothers, New York; "The Fetal Pig–A Photographic Study," Rinehart and Company, New York; "Structure and Development of the Frog–A Photographic Study," Rinehart and Company, New York; "Laboratory and Field Studies in Biology," Holt, Rinehart and Winston, Inc.; "Plant Growth and Development," BSCS. Author, "Texas Junior Academy of Science Bulletin of Information," "Biology, The Science of Life," "Teachers Manual for Biology, The Science of Life." Editor, "Proceedings of the Texas Work Conference for Advancement of Science Teaching and Science Fairs." Articles in: *The Science Teacher, ABT, The Texas Outlook, The Texas Interscholastic Leaguer, Transactions and Proceedings of the Texas Academy of Science, Tasca, School Science and Mathematics, The Metropolitan Detroit Science Review, Elementary School Science Bulletin, American Journal of Botany, Bulletin of the Torrey Club,* and *Botanical Gazette.*

Candidate for First Vice-President

Abraham M. Weckstein

Present Position: Coordinator of Science and Mathematics K-12, Bridgewater Township Public Schools, New Jersey.

Degrees: B.S. with Honors in Biology, New York University. M.A., Columbia University. Ph.D., New York University.

Experience: Teaching Fellow in Biology, New York University. Teacher of Biology, Chemistry, and General Science in Newark, New Jersey high schools. Science Department Chairman in New Jersey schools. Instructor, New Jersey State Teachers College, Rutgers University, Trenton State College. Wortis Prize in Biology, New York University. Fellow, Fund for the Advancement of Education, Ford Foundation. Radiation Biology Institute, Duke University; Research Participation Program, Newark College of Engineering. Holder of grant for Ultrasound Research, Newark College of Engineering. Advanced training at the Marine Biological Laboratories, Woods Hole, Massachusetts. Officer, Hospital Service Corps, U. S. Naval Reserve. Has appeared on numerous radio, television, and educational scientific programs as consultant and participant. Assisted in organizing Greater Newark Science Fair and New Jersey State Science Day. Judge, Science Fairs. Member, First Edison Foundation Institute. Consultant in setting up Standard Oil Science Fellowships.

NABT Activities: New Jersey State Membership Chairman. Participant in local and national meetings. Book reviewer for *ABT.*

Organization Membership and Activities: Past-President, New Jersey State Science Teachers Association. Regional Director, Future Scientists of America Foundation. Past-President, Phi Beta Kappa Alumni, Essex County, New Jersey. Member, Standing Committee II, NSTA. Member, AAAS, NEA,

NJEA, NCTM, Summit Association of Scientists, Phi Beta Kappa, Beta Lambda Sigma, AIBS.

Publications: Author, Biology Texts, Workbooks, Standardized Tests, and "Medichrome Slides" in Biology for Clay-Adams Company. Item Writer, Educational Testing Service. Past Editor, *New Jersey Science Teacher*. Articles in: *Science Education, Journal of the American Medical Association Naval Medical Bulletin, Metropolitan Detroit Science Review, Military Surgeon, Hospital Corps Quarterly, ABT, Transactions of the New York Academy of Science.*

Candidate for Second Vice-President

Sister Mary Gabrielle

Present Position: Principal, Holy Trinity High School, Hartford, Connecticut.

Degrees: B.Sc., Duquesne University, Pittsburgh, Pennsylvania. M.S. and Ph.D., University of Pittsburgh.

Experience: Teacher and principal for some 30 years in the elementary and secondary schools of Michigan, Pennsylvania, and Connecticut. Teaching staff of Duquesne University Summer School and In-Service Training.

NABT: National Chairman of Catholic Schools Membership Committee. Past member of the editorial staff of *ABT*. Member, Liaison Committee.

Organization Membership and Activities: Chairman of Biology Section, Vice-president, Diocesan Science and Mathematics Teachers Association. Inaugurated the Biology Institute Day at Duquesne University. Assistant Director of the Pennsylvania Junior Academy of Science. Regional Chairman of Pittsburgh Section of Pennsylvania Junior Academy of Science. Member, editorial staff of the *Science Counselor*. Present member, editorial staff of "Vistas in Science" of the Future Scientists of America. Member, NCEA, NSTA, Allegheny Scholarship Association, AIBS, Pennsylvania Academy of Science, Western Pennsylvania Biology Teachers' Association. Member of Planning Committee, 1961 NSTA Convention in Chicago. Member, Election Committee, NSTA, 1962.

Publications: Presented research papers at Pennsylvania Academy of Science. Publications in *ABT, Science Counselor, Proceedings of Pennsylvania Academy of Science*. Published proceedings of Biology Institute Day held at Duquesne University.

Candidate for Second Vice-President

Sister Hilaire, O.S.F.

Present Position: Chairman and Professor of Biology, Rosary College, River Forest, Illinois.

Degrees: A.B., M.A., and Ph.D., University of Illinois.

Experience: Professor of Biology, College of New Rochelle, New Rochelle, New York. Participant, School and College Workshop, University of Chicago. Participant, Summer Institute for Teachers of College Botany, Cornell University. Teaching Assistant, University of Illinois. Research, Institutum Divi Thomae.

NABT Activities: Participant, North Central States Conference for Biology Teachers. Member, Illinois State Membership Committee. Chairman, Catholic Membership Committee.

Organization Membership and Activities: Member, AIBS, AAAS, Botanical Society of America, Mycological Society, Genetics Society, Torrey Botanical Club, AAUP, Mid-West Conference of College Biology Teachers, Sigma Xi, Sigma Delta Epsilon, and Illinois Academy of Science.

Publications: Microthyriaceae, *Mycologia* and *University of Illinois Monograph* series. "Effects of Water Source on Toxicity of Mercurial Poisons," *Journal of Heredity*, 1951.

Candidate for Third Vice-President

Robert L. Smith

Present Position: Chairman, Biology Department, DeKalb High School, DeKalb, Illinois.

Degrees: B.E., Illinois State Normal University, M.A., (zoology), University of Michigan.

Experience: State chairman, Illinois Junior Academy of Science, 1949-51. Elementary science consultant, Illinois Department of Public Instruction. Participant, Darwin Centennial Celebration, University of Chicago.

NABT Activities: State and Regional Chairman, Conservation Project. National Membership Chairman since 1955. Participant, North Central Conference on Biology Teaching.

Organization Membership and Activities: Member, ANSS, NSTA, AIBS, Illinois Junior Academy of Science, Northern Illinois Association of Biology Teachers.

Publications: Contributing author, *NABT Conservation Handbook.* Article on biology clubs in *ABT.*

Candidate for Secretary-Treasurer

Herman C. Kranzer

Present Position: Associate Professor of Elementary Education, College of Education, Temple University, Philadelphia, Pennsylvania.

Degrees: B.S., (forestry), M.A., (education), University of Michigan; Ed.D., U. C. L. A.

Experience: Taught science and conservation, Work-Learn Camp for Older Youth, Michigan. Teacher counselor, Clear Lake Camp, Battle Creek Schools. Outdoor Education Director, Culver City, California. Director, Conservation Workshop, West Chester State College, Pennsylvania. NDEA lecturer in elementary science. Director, Conservation Education Laboratory for Teachers, Pennsylvania State University. Assistant Professor of Science Education, Pennsylvania State University. Director, In-Service Institute for Elementary School Teachers of Science.

NABT Activities: Secretary-Treasurer, 1961.

Organization Membership and Activities: Member, NSTA, Pennsylvania Science Teachers Association, Conservation Education Association, Phi Delta Kappa, NARST. Board of Directors, Pennsylvania Forestry Association. NSTA Teaching Materials Review Committee.

Publications: "Education in the Out-of-Doors," Pennsylvania School Study Council. Bulletin of the Michigan Secondary School Association. "A Community School Work-Learn Camp," Michigan Department of Public Instruction. Article in *Metropolitan Detroit Science Review.*

Candidate for Recording Secretary

Audrey E. Pressler

Present Position: Biology Teacher, Frederick High School, Frederick, Maryland.

Degrees: A.B., Hood College. M.S., University of Michigan.

Experience: High school biology teacher for many years. Participant, NSF Summer Institute for teachers of High School Biology, Indiana University. Writing Conference for Sourcebook, Michigan State University. Awarded NSF fellowship for University of Michigan. NSTA STAR program winner.

NABT Activities: State Membership Chairman, Maryland. Member, Conservation Committee. Local chairman, AAAS meetings, 1958. Recording Secretary, 1961.

Organization Membership and Activities: Member, NEA, NSTA, AIBS. Reviewer, AIBS Film Series. Member, Welfare and Nominating Committees, Maryland State Teachers Association. President, Maryland Science Teachers Association. Secretary and Member of Board of Trustees, Maryland Biology Teachers Association. Member of Executive Committee and Chairman of Teacher Welfare Committee, Frederick County Teacher's Association. Corresponding Secretary, Frederick County Science Teachers Association. Past President, Junior Woman's Club and Frederick Hood Club.

Publications: Article in *The Science Teacher.* One of authors, *Laboratory and Field Studies in Biology.*

Candidates for Regional Directors

Region 1 (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont)

John K. Bodel

Present Position: Head, Science Department, The Hotchkiss School, Lakeville, Connecticut.

Degrees: A.B., Wesleyan University. A.M. and Ph.D., Harvard University.

Experience: Further study at Columbia University, University of Michigan Medical School, Audubon Nature Camp, and Massachusetts Institute of Technology. Held a Westinghouse Scholarship. Teacher of general science, chemistry, and biology. Participant, Writers' Conference, BSCS.

NABT Activities: Member, Liaison and Institutes Committees.

Organization Membership and Activities: Member, Education Committee, AIBS; Advisory Committee, College of the Air television program, "The New Biology." Chairman, Steering Committee, AIBS Film Series. Member, AIBS, Connecticut Science Teachers Association, American Anthropological Association, Society for Child Welfare and Development, American Association of Physical Anthropologists, National Council for Measurements in Education.

Publications: Biology questions, Educational Testing Service. Biology tests, Educational Records Bureau.

Irving Keene

Present Position: Biology teacher, Weston High School, Weston, Massachusetts.

Degrees: B.S., Middleburg, College. M.Ed., Boston University.

Experience: Biology teacher in secondary schools for over 30 years. Graduate study at Harvard and Cornell. Organized first Science Fair in Massachusetts. speaker at various meetings. Developed Plant and Wildlife Conservation Center, Brookline, Massachusetts.

NABT Activities: Local chairman, AAAS meetings in Boston, 1944 and 1950. Managing Editor, ABT, 1947-49. Regional membership chairman since 1955. Planning Committee, North Central Conference on Biology Teaching, 1955. Member, Nominating Committee, 3 years. Second Vice-President, 1958.

Organization Membership and Activities: Member, AIBS. Past President, New England Biological Association. Chairman, New England area, Natural Areas for School Grounds, sponsored by Nature Conservancy.

Publications: Articles in *ABT*.

Region IV (Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota)

Ronald K. Gibbs

Present Position: Biology instructor and science-department head, Alexander Ramsey High School, St. Paul, Minnesota.

Degrees: B.S., M.S., University of Wisconsin.

Experience: Biology teacher in Rice Lake, Wisconsin, for seven years and at present position for the past four years. Assistant director of science institute for high school biology teachers preparing to use the blue version of the BSCS, State College of Iowa, 1961.

NABT Activities: Member of the Summer Writing Conference of BSCS. Presently engaged in testing and evaluating the blue version of the BSCS material and the block program, "Interdependence of Structure and Function."

Organization Membership and Activities: Member, Minnesota Academy of Science, NSTA, State Science Curriculum Committee, AIBS. Participant, Darwin Centennial Celebration, University of Chicago.

Publications: Minnesota Academy of Science Journal, "A Saturday Morning Science Enrichment Program."

Clarence T. Lange

Present Position: Science Consultant in Biology, Missouri State Department of Education, Jefferson City, Missouri.

Degrees: B.S., M.S., Colorado State University.

Experience: Seven years in biological research; 5 years classroom experience. Member, Committee on Education of Society of American Bacteriologists, 1959-60. Helped develop June, 1960, special microbiology issue of *ABT*. Guest lecturer at Traveling Science Teacher Institute, Oklahoma State University, Stillwater, 1961. Participation in BSCS Program. In second year of conducting Radiation Biology workshops for secondary science instructors. Chairman, committee developing radiation biology block proposal for BSCS.

NABT Activities: Active in soliciting members in Missouri.

Organization Membership and Activities: Member, NSTA, NEA, Beta Beta Beta, Missouri Science Teachers Association, National Science Supervisors Association, AIBS.

Publications: Several technical papers. Thesis summary published in *Phytopathology*, Article in *ABT*.

Region V (Delaware, Maryland, District of Columbia, Kentucky, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia)

William Foil

Present Position: Biology teacher, Hanes Senior High School, Winston-Salem, North Carolina.

Degrees: B.S., M.Ed., University of North Carolina.

Experience: DuPont Fellowship, University of North Carolina, 1954. Summer and In-Service Institutes. Participant, NSTA Regional Conference, 1960.

NABT Activities: State Membership Chairman.

Organization Membership and Activities: Member, NSTA, AIBS, NEA, North Carolina Education Association, AAAS, Phi Delta Kappa, Sponsor, Key Club, Science Club, After-School Science Program.

Alfred Wolfson

Present Position: Head, Department of Biological Sciences, Murray State College, Murray, Kentucky.

Degrees: B.S., Cornell University, M.A. and Ph.D., University of Wisconsin.

Experience: Research Fellowships from Belgian-American Educational Foundation, National Research Council, Research Botanist, United Fruit Company. College teacher of biology for 30 years. Director of five NSF In-Service Institutes and five NSF Summer Institutes for High School Science Teachers.

NABT Activities: State Membership Chairman for Kentucky.

Organization Membership and Activities: Fellow, AAAS. Member, Botanical Society of America, AIBS, AAUP, Sigma Xi. Past President, Kentucky Academy of Science.

Publications: Several papers on morphology and cytology of liverworts. Several laboratory manuals for college courses in biological sciences.

Region VII (Arkansas, Arizona, New Mexico, Oklahoma, and Texas)

Ruth B. Thomas

Present Position: Professor of Biology, Eastern New Mexico University, Portales.

Degrees: B.S., Northwestern College of Louisiana. M.A., Peabody College. Ph.D., Vanderbilt University.

Experience: Taught in public schools of Louisiana, Millikin University, Peabody College, Sullivan College.

NABT Activities: State Membership Chairman of New Mexico.

Organization Membership and Activities: Fellow, AAAS. Vice-Chairman, Botanical Section, Rocky Mountain Southwestern Division of AAAS. Member, New Mexico Academy of Science, Botanical Society of America, AIBS, AAUP, Delta Kappa Gamma, Altrusa, Sigma Xi. Involved in Science Fair Activities.

Publications: "Reproduction in *Pinus virginiana.*"

Joe W. Tyson

Present Position: Biology, physiology, and physics teacher, William B. Travis High School, Austin, Texas.

Degrees: B.S., M.S., North Texas State College, Denton.

Experience: Science teacher for 14 years. Participant, Radiation Biology Institute. Participant, Darwin Centennial Celebration. Member, AIBS Visiting Lecturers Program. Consultant, Corpus Christi Public Schools, AIBS Film Series, Laboratory Innovations Subcommittee, BSCS.

Organizations: Member, Beta Beta Beta, Phi Delta Kappa, Texas Academy of Science, TSTA, AIBS.

Publications: "Atomic Radiation in the High School Science Class."

Region VIII (Colorado, Idaho, Montana, Nevada, Utah, and Wyoming)

Richard G. Beidleman

Present Position: Associate Professor of Zoology and Director of NSF Institutes, Colorado College, Colorado Springs, Colorado.

Degrees: B.A., M.A., Ph.D., University of Colorado.

Experience: Fourteen years of teaching at college level, including Colorado State University, University of Colorado, and Colorado College. Visiting lecturer at University of Denver, Colorado State College, Western State College, North Dakota Agricultural College, and University of Oklahoma Geology Field Camp. Director of three NSF summer institutes, three NSF secondary school student programs, and an NSF general science in-service institute at Colorado College. Director of the NSF Colorado-Wyoming Academy of Science Visiting Scientist Lectureship Program for three years and the Deep Springs Science Enrichment Program for high-ability elementary school students. AIBS visiting biologist (college) program and AIBS Film Series lecturer. Seasonal ranger-naturalist and interpretative planner, National Park Service, since 1948. Fund for the Advancement of Education grant, 1954-55.

NABT Activities: State Membership Chairman of Colorado.

Organization Membership and Activities: Member, NSTA, Sigma Xi, Phi Sigma, Ecological Society of America, American Society of Mammalogists, AOU, Cooper Ornithological Society, History of Science

Society, Society for the Study of Evolution, American Society of Zoologists, AAUP, American Society of Ichthyologists and Herpetologists, Wilderness Society, AIBS, Wildlife Society, Society of Bibliography Natural History. Fellow, AAAS. Executive Secretary, Colorado-Wyoming Academy of Science. Regional Director, Beta Beta Beta, 1950-56.

Publications: 150 popular and technical publications in the fields of science and history of science in such periodicals as *School Science and Mathematics, Proceedings of the American Philosophical Society, Proceedings of the U. S. National Museum, Audubon Magazine, Natural History, Nature Magazine, Frontiers, Pacific Discovery, Condor, Journal of Mammalogy, Copeia, Turtox News, Audubon Field Notes, Delphian Quarterly*, and others.

Jerry P. Lightner

Present Position: Biology Teacher, Great Falls High School, Great Falls, Montana.

Degrees: B.S., Wayne State College, Nebraska. M.A., Colorado State College, Greeley, Ed.D., Colorado State College (to be conferred December, 1961)

Experience: Nine years high school biology teaching. Teaching assistant, Colorado State College. Participant, University of South Dakota NSF Academic Year Institute.

NABT Activities: None.

Organization Membership and Activities: Member of NABT, AIBS, NSTA, AAAS, NEA, and MEA.

Publications: "The Status of Advanced Biology in Large Secondary Schools of the United States." Articles on Advanced Biology in the *ABT*.

Region IX (Alaska, California, Oregon, Washington, and Hawaii)

Mary R. Ames

Present Position: Biology teacher, Ballard High School, Seattle, Washington.

Degrees: B.S., Wisconsin State College, River Falls. Completing Master of Basic Science graduate work at the University of Colorado.

Experience: Nine years of teaching, Wisconsin, Minnesota, and including five years at the present position. Participating in the BSCS program, Blue Version. Participated in the Harvard Science Case Study program during 1960-61. Using the TV course "New Biology" this year with Biology 3 class. Nominee to the John Hay Fellowship program 1959-60. Chairman of Reference Book Adoption Committee for Biology in Seattle. Sponsor, Science Club. Participated in Science Clubs of America workshop held in Seattle last spring.

NABT Activities: State Membership Chairman for Washington for three years.

Organization Membership and Activities: Secretary-Treasurer, Seattle Association of Science Teachers. Member, NSTA Evaluation Committee of Business Sponsored Teaching Materials.

Edith Curry

Present Position: Biology Teacher, Grossmont Union High School District, El Cajon Valley High, El Cajon, California.

Degrees: A.B., Yankton College, Yankton, South Dakota. M.S., University of Nebraska, Lincoln.

Experience: Teaching assistant, University of Nebraska and Oregon State College. Biology and chemistry teacher, Central High School, Sioux City, Iowa; Rochester Junior College, Rochester, Minnesota; Astoria High School, Astoria, Oregon. Staff: NSF Institute, Southern Oregon College, Ashland, Oregon. Participant NSF Institutes at New Mexico Highlands University and in Radiation Biology at the University of Wyoming.

NABT Activities: Membership Chairman, Southern California. Regional Editor, *ABT*.

Organization Membership and Activities: Member, Sigma Xi, NSTA, AIBT, NEA, CTA. Past-President, Western Region, ANSS. Member of teaching staff at camp two summers, Screen Tours Chairman, Vice president, San Diego Audubon Society. Past board member of Orange and San Diego County chapter, Nature Conservancy. Secretary, local chapter, Delta Kappa Gamma. Secretary, LaMesa Branch, AAUW.

Publications: Articles in *Journal of Morphology, ANSS Bulletin.*

Book Reviews

Science Projects

THE SCIENTIFIC AMERICAN BOOK OF PROJECTS FOR THE AMATEUR SCIENTIST, C. L. Stong, 584 pp., $5.95, Simon and Schuster, Inc., New York, 1960.

There is division among science teachers on projects, and there are attacks on the whole scheme being incorporated into the school science curriculum, but there is no doubt that projects are currently an important part of science teaching. The foreword to this work by Vannevar Bush gives a beautiful defense of the amateur

scientist and his "projects." If for no other reason, this book should be used for this clear and logical statement in defense of the amateur, and this is what the student is in your classes.

The major part of the book is devoted to reprints of the most valuable projects for amateurs which have been carried in *The Scientific American*. As all science teachers know, these ideas are high level but feasible for the careful student, regardless of level. In fact, many of these are written by high school students. They are organized into the various disciplines. However, there is a strange absence of those in chemistry, although chemistry is used in a great many others. They are written in clear and detailed fashion, in a manner calculated to inspire the amateur to do more on his own. The excessive shading in many sketches obscures many details, and this reviewer would have preferred more simple line diagrams.

But this should be on every science library book shelf. In fact, many teachers and students will want their own copies. Highly recommended.

P. K.

THE LIVING LABORATORY, 200 EXPERIMENTS FOR AMATEUR BIOLOGISTS, James Donald Witherspoon and Rebecca Hutto Witherspoon, 256 pp., $3.95, Doubleday and Company, Garden City, New York, 1960.

An answer to the biology teacher's plea for a handy book for students interested in "doing a project." The authors are members of the Purdue University staff, but in the Acknowledgements well known members of NABT are listed including ABT Assistant Editor, William Kastrinos. The book is the result of requests made by members of the NSF Summer Institute at Purdue.

The book consists of elaborately annotated fields for project work. Thus, for example, one chapter on "Animal Intellect," lists equipment for a maze, suggestions for experiments, a brief bibliography, and some background information. In reading the book critically, one is tempted continually to suggest other projects for each chapter. Also, it seems that the background material is sometimes more detailed than necessary for a student who is willing to use his own textbook. The discussion of cells, for instance, only casually mentioned tissue culture without helping the student. There are useful appendices. One is tempted to wonder how anti-vivisectionist groups will view some of the animal experimentation. However, all in all, this is a highly recommended book for the weary teacher who must answer her student's plea, "I want to do a project, but what can I do?"

P.K.

PROJECT IDEAS FOR YOUNG SCIENTISTS, John K. Taylor, Phoebe Knipling, Falconer Smith, 142 pp., $1.25, Joint Board on Science Education, Washington 5, D. C., 1960.

This is one of the best detailed listing of high school science projects this reviewer has seen. Further, it is a visible evidence of the type of cooperative effort present in the Washington area for improved science teaching. Projects are listed into the main divisions of the local science fair. References are listed for most, and each project has a one or two paragraph explanation. There are also cross-referenced appendices. There are also excellent general project suggestions which are quite pertinent. It is unfortunate that the student is not warned to not send meaningless letters of request to scientists which have become quite a problem. However, perhaps the detailed aids listed here will make this unnecessary. The book is offered at cost. Congratulations to the authors and the Washington Joint Board of Science Education.

P.K.

Science Teaching Methods

POLICIES FOR SCIENCE EDUCATION, Frederick L. Fitzpatrick, 219 pp., $3.95, Bureau of Publication, Teachers College, Columbia University, New York, New York, 1960.

To the science teacher who has given serious thought to the problems that beset science education, reading *Policies for Science Education* will give that feeling of "having been here before" often experienced by travelers and people in new situations and circumstances. In this case the feeling will be justified and not due to tricks of the imagination or memory. They (science teachers) have been here; they are here; they will be here at least for some time. That is to say, the material covered in the book is well known to most science teachers.

Believing this or finding it to be true, one might ask "Is there need of a guide-book to our own city?" While it is probably true that

most science teachers are aware of and concerned with the problems in science education, we must acknowledge the possibility that some are not and that the plight of science education does not rest solely in the hands of science teachers. It is to lay people and less experienced science teachers with responsibility for policy formation in science education that I particularly recommend this book.

Policies For Science Education is a well ordered, statement of current thought and information pertaining to science education. It is more of a call to arms and a plan for battle than it is the disclosure of revolutionary new and secret weapons. Some new and interesting ideas are presented, but for the most part it represents a realistic appraisal and a call for action. The following from the book might serve to illustrate this pattern.

"The typical school principal has a multitude of administrative duties. He is the one who has direct liaison with the superintendent of schools and, through the latter, with the board of education. At the same time, he is a member of the faculty and in many cases considers himself as much responsible for the teaching and guidance of students as any of the teachers on his staff. So far as science education and guidance are concerned, the principal has a number of critical functions. His own attitude toward and concern for science teaching may well set the standard for what is accomplished in his school . . . ."

The above paragraph represents what I have referred to as the "appraisal phase" of the book's pattern. The next paragraph, quoted in part, follows the one just quoted and represents the "call for action" phase of pattern.

"If the principal actively encourages improvement of science teaching, more students in his school may be attracted into science courses. The principal should give close attention to the school's science program, and should encourage his science teachers to modify the courses when necessary. He can give encouragement to the teachers themselves by recognizing their special problems and making adjustment to allow for them. He can be especially helpful by providing good teaching schedules, reasonable teaching loads, time for special classroom and laboratory preparation, and adequate budgets for needed equipment, supplies, and reference books. . . ."

I agree: I am sure a lot of teachers will; I hope that a good many lay people will have the opportunity to do so.

Gregg R. Scarborough
State University Teachers College
Brockport, New York

New Developments in High School Science Teaching, National Science Teachers Association, 108 pp., $1.50, National Science Teachers Association, 1201 Sixteenth Street, N.W., Washington 6, D. C., 1960.

This booklet is the report of a study supervised by Margaret J. McKibben, Assistant Executive Secretary for Special Projects of the National Science Teachers Association. It contains valuable information for teachers, supervisors, administrators, and curriculum planning groups revising and planning new programs.

Many specific programs which have been through a tryout period are described in the areas of general science, earth-space science, biology, physical science, chemistry, and physics. Equally impressive are descriptions of some of the administrative provisions which have been made to extend the school science program to out-of-school hours.

A majority of the new developments are provisions for the academically talented. This is representative of the recent increased effort in behalf of youth of greater than average ability and interest in science.

Of great value is the portion of the report that lists the names of schools, school systems, and agencies willing to supply printed materials providing information about such new practices.

Don Winslow
University High School
Bloomington, Indiana

Star '60, Selected Papers on Science Teaching, Abraham Raskin, Editor, 64 pp., $1.00, National Science Teachers Association, Washington, D. C., 1960.

This is the familiar annual report of selected reports from a deservedly famous program of honoring science teachers. Certainly, these are the best of the series. Congratulations are in order to the National Cancer Institute and the NSTA for their sponsorship. It is interest-

ing to note that of the 13 papers published, 7 are clearly in the biological sciences, 3 in general teaching methods, and 3 in the physical sciences. The papers are fully illustrated. Very valuable for every science teacher.

P.K.

QUALITY SCIENCE FOR SECONDARY SCHOOLS, National Science Teachers Association, 210 pp., $3.00, National Science Teachers Association, Washington 6, D. C., 1960.

The NSTA has cooperated with the National Association of Secondary-School Principals in preparing its December, 1960 issue of *The Bulletin* which is the official publication of the NASSP. One of the major purposes of this "hard bound" copy of *The Bulletin* is to help define the kinds of attitudes and understandings that science teachers need if they are to engage effectively in planning and directing improvements in science programs. However, greater emphasis is placed upon the role of the administrator in improving the science program.

In quest for better science education, the principal will find the content useful as he assumes a leardership role in curriculum redesign in these days of concern and ferment in the field of science. Particular attention is given in an attempt to integrate the elementary-school work with the secondary science curriculum. From the title, throughout the book, the basic emphasis for the improvement of science education in this issue of The Bulletin is upon planning to improve the "quality" of the program rather than the quantity of the material included.

One of its greatest strengths is that the contributors to this publication are engaged actively in science programs from the kindergarten through college. They have given special references to a continuous science program and have called attention to new programs and materials relating to specific courses in the junior and senior high schools.

Don Winslow
University School
Indiana University

PLANNING FOR EXCELLENCE IN HIGH SCHOOL SCIENCE, National Science Teachers Association, 67 pp., $1.00, National Education Association, Washington 6, D. C., 1961.

For the size of the pamphlet and the time that it takes to read it, every science teacher stands to profit from the challenge alone that asks each teacher to re-examine and to reconsider his goals, and then to take the appropriate action that is necessary in his field of endeavor to keep his goals valid in terms of contemporary thought and culture.

By no means can a booklet of this type exhaust a treatment of the problems involved in the analysis of our educational and scientific enterprise, but it certainly calls to the attention of the classroom teacher the need of re-evaluation in planning for excellence in science.

An attempt is made to focus on the whole range of problems which relate to the secondary school science program. Some consideration is given to a discussion of the implications for teacher competence, teacher preparation and to the identification and recruitment of science teachers in addition to a chapter dealing with the implications for secondary school science. Many questions are raised to which active science teachers must quantitatively and qualitatively respond in the examination, reorganization, and reconstruction of our educational processes.

Don Winslow
University School
Indiana University

TEACHING SCIENCE THROUGH CONSERVATION, Martha E. Munzer and Paul F. Brandwein, 470 pp., $7.50, McGraw-Hill Book Company, Inc., New York, 1960.

It is hard to see how a course to teach science teachers can do without this book. But more importantly, it is an amazing handbook to which every science teacher should have access. Written by two skilled writers, this book is the result of a great deal of work and carries the endorsement of the Conservation Foundation. All concerned are to be congratulated.

The organization of the book is unique. For example, there are two Tables of Contents, depending on how the reader wishes to use the book. Not much time is wasted on lengthy definitions and panegyrics to conservation, but these statements are clear and precise. The last chapter is an extensive review of schemes to work with the gifted science student as "Our Future Resource." The appendix and bibliography are beautifully done.

The organization of the main body of the book is like a general science book. There are a great many orthodox laboratory and classroom exercises found in general science, biology, chemistry, and physics courses, but each is related to its conservation implication. But there is an amazing number of new and clever exercises of a high level of sophistication. It is hard to see why conservation needs to be taught as it frequently is, if this book is used. The authors are fully aware that conservation is most often taught throughout all science courses rather than as discrete units. This book shows how it can be done in a better way.

A must book for all teacher training programs and all high school science libraries. The best to date.

P. K.

SUCCESSFUL SCIENCE TEACHING, Milton S. Lesser, 64 pp., $1.75, Teachers Practical Press, Inc., Valley Stream, Long Island, New York, 1961.

Most of this little book is devoted to the construction of an appropriate lesson plan, and thus a great variety of such plans are discussed in relation to types of lessons, objectives, etc. It is written by a well known and successful teacher whose ideas should be studied in the improvement of teaching. Should be useful in the methods course, and particularly by teachers who need some help in improving their pedagogical approaches and planning.

P. K.

YOUR SCIENCE FAIR, Arden F. Welte, James Dimond, and Alfred Friedl, 103 pp., $2.75, Burgess Publishing Company, Minneapolis, Minnesota, 1959.

The title of this paperback is self-explanatory and probably of value to those in the business of initiating and administering a science fair. There is some space devoted to some project reports by students to show different types of work. There are many pictures of fair exhibits. Most of the book is devoted to helpful hints in running a science fair. However, there does not seem to be clear admonitions for projects beyond the building and collecting types. Perhaps the author accepts these as proper projects.

P. K.

LABORATORIES IN THE CLASSROOM, 96 pp., $1.45, Science Materials Center, Inc., New York, 1960.

This is a collection of short essays by authorities in each of the fields covered. Starting with Fletcher Watson and ending with Morris Meister, there is an amazing collection of talent in this small book. There is an emphasis on the philosophy and status of science education, some of the new developments in teaching, and some of the implications of well-developed science teaching materials. While there is little that is new in the booklet, it is a fine thing to have between two covers some of the new developments in science education. The emphasis is on the need for student experimentation as a classroom learning necessity in science.

P. K.

Science Teaching Aids

EFFECTIVE READING IN SCIENCE, David L. Shepherd, 128 pp., Row, Peterson and Company, Evanston, Illinois, 1960.

Every science teacher complains about the inability of students in reading in science books, but few know what to do about it. This book gives some effective lessons on how the science teacher can help the student in science reading. It is written primarily for high school teachers and gives interesting ideas.

The organization of the book lists some of the characteristics of the skills necessary for such reading, and then launches into some chapters to explain them still further. A check list for teachers concludes the book, and it is a valuable one for all science teachers. Some information is given about diagnostic and evolution tests. It seems rather needless to review the scientific method, but not too much space is wasted on this. However, this reviewer is not very happy that the author has chosen a dialogue method to put across the ideas in most of the chapters. While this can easily show how ideas can be developed, it does make for laborious reading. But do not let that dismay the potential reader. The book *is* good, and should be the answer to a perennial complaint.

P. K.

A CRITICAL INDEX OF FILMS AND FILMSTRIPS IN CONSERVATION, Audio-Visual Department of The Conservation Foundation, 69 pp., no charge, The Conservation Foundation, New York, 1960.

As the title indicates, this is a critical, annotated listing of conservation films available for classroom use. It is well done and useful. One interesting feature is selected lists of films chosen by audio-visual and science consultants. The publication is available without charge from the Conservation Foundation, 30 East 40th Street, New York 17, New York. Send for one today.

P.K.

EDUCATORS GUIDE TO FREE SCIENCE MATERIALS, Mary Horkheimer Saterstrom and John W. Renner, Editors, 298 pp., $6.25, Educators Progress Service, Randolph, Wisconsin, 1960.

This paper-back in photo-offset using typewriter print lists audio-visual materials available for science teaching with cross reference listings of companies issuing, the title headings. The chief listing is by subject areas.

About one-fourth of the book is devoted to teaching units in all sciences, elaborately developed, showing how the materials may be employed. The biology units are on plant hormones and radiation biology. The same type face throughout the book makes for difficult reading and reference work, but once the system is caught, it becomes fairly easy. An elaborate introduction does not seem to lend much to the book. Most valuable for the audio-visual person who must find the best in the field. Produced in cooperation with NSTA.

P.K.

FREE AND INEXPENSIVE EDUCATIONAL AIDS, Thomas J. Pepe, 287 pp., $1.35, Dover Publications, Inc., New York, 1960.

As the title indicates, this is an excellent listing of pamphlets, booklets, films, folders, charts, and picture sets chiefly available from industries and commercial organizations. The organization of the listing is well done with an index containing many cross-references. Over fifty-nine categories are listed. There is also a listing of the companies involved and their addresses. It will be a handy listing for the science teacher but especially the school librarian who wishes to build up her vertical file.

P. K.

STYLE MANUAL FOR BIOLOGICAL JOURNALS, Committee on Form and Style of the Conference of Biological Editors, 92 pp., American Institute of Biological Sciences, Washington 6, D. C., 1960.

Already a best seller, with a surprising distribution, this guide will be the official guide for this journal which participated in its preparation. While the current style of the ABT differs in some respects from the recommendations of this guide, eventually this journal will conform to its format. See the article by John Breukelman in the October, 1961 issue for further details. Prospective authors who have not published before should use this manual in the preparation of their manuscripts.

P. K.

PROCEEDINGS OF THE INDIANA ACADEMY OF SCIENCE FOR 1959, Vol. 69, Richard A. Laubengayer, Editor, 347 pp., Indianapolis, Indiana, 1960.

These annual proceedings record the papers in the sections from anthropology to zoology. Summaries and full papers with illustrations are included. A similar treatment is included for the meetings of the Junior Academy of Science. Biology teachers will find several papers of real interest: earthworms, pollen studies, bryophytes, water beetles, etc. Teachers looking for good project ideas might consult this and similar volumes from other state academies.

P.K.

HENDERSON'S DICTIONARY OF SCIENTIFIC TERMS, SEVENTH EDITION, John H. Kenneth, xv + 595 p. $12.50, D. Van Nostrand Co., Princeton, New Jersey, 1960.

The seventh edition of *Henderson's Dictionary of Scientific Terms,* like the earlier editions, carries the sub-title "Pronunciation, Derivation, and Definition of Terms in Biology, Botany, Zoology, Anatomy, Cytology, Genetics, Embryology, Physiology." It is unfortunate that the term, biological, is not substituted for "scientific" in the main title, for this *is* a biological dictionary.

To evaluate a work of this kind, one must consider the way it will be used as a reference. Ideally, a biological dictionary should serve the scientist in reading any biological work—even those a century or two old as well as current literature. It should indicate the different ways words have been used by different writers and should cite references to these uses. In this way it would go beyond the standard reference dictionaries and would, if comprehensive, run into several volumes. Such an "Oxford Dictionary" of biological science would be of great value, but it is unlikely that it will be written. Lacking such a work, one must search for the best technical dictionary available.

It is the opinion of this reviewer that Kenneth's book is the best available. The dust cover states that 1750 new terms have been added to bring the present edition to a total of 15,600 words. An attempt has been made to make the work cover American as well as British usage with respect to spelling and pronunciation. No attempt is made to give references or the history of the biological use of the terms. In a small sample of words taken at random, it was found that most, but not all, were also to be found in an unabridged dictionary (*Merriam Webster's New International Dictionary, 2nd Ed.*) and that the definitions of biological usage were similar in the two books. The biological usages were easier to find in the smaller work. This book should be on every biologist's reference shelf.

John M. Hamilton
Park College
Parkville, Missouri

THE BIOLOGIST'S HANDBOOK OF PRONUNCIATIONS, Edmund C. Jaeger, xvi + 317 p., $6.75, Charles C. Thomas, Springfield, Ill., 1960.

The problem of the correct pronunciation of technical terms is a serious one for beginners in biological science, and the problem is compounded by the errors made by their teachers. This book by Dr. Jaeger, therefore, fills a real need. In it are found the commonly used and mispronounced technical terms, many generic names of plants and animals, and numerous adjectives used as specific or trivial names. The introduction contains a brief compilation of the rules of pronunciation of Latin terms.

Most of us who use the technical language of biology will find pronunciations in this book which are at variance with the way we say the words. Sometimes we may argue that "our way" has the support of common usage. Frequently, however, "our way" was adopted because we guessed the proper pronunciation when we did not have a reference to check the word in question. Dr. Jaeger's book is small enough to be easy to use and comprehensive enough to be useful. It is hoped that its wide use will lead to greater uniformity and accuracy in the pronunciation of biological terms.

John M. Hamilton
Park College
Parkville, Missouri

Education

FELLOWSHIPS IN THE ARTS AND SCIENCES, 1961-1962, Michael Edmind Schiltz, 149 pp., $3.00, American Council on Education, Washington, D. C., 1960.

Another edition of a most valuable publication for those seeking financial assistance for graduate work. There is a good introduction on procedures in fellowship and scholarship applications. The listings of available fellowships is most complete and detailed.

P. K.

ARE SCHOOL TEACHERS ILLIBERALLY EDUCATED? Earl J. McGrath and Charles H. Russell, 28 pp., $1.00, Bureau of Publications, Teachers College, Columbia University, New York, 1961.

The main thesis of this monograph is that the percent of professional (education) courses for teacher training in certain institutions in the AACTE is an average of 36% for elementary teachers and 17% for secondary teachers. The authors do not believe this excessive and compare these percents with the time in professional courses in agriculture, business administration, engineering, music, nursing, and pharmacy. There the percentages range from 36% to 68% for professional work. Thus, teachers are more liberally educated than those in the other fields cited. The authors quote liberally from their previous publications.

P. K.

THE QUANTITY AND QUALITY OF COLLEGE TEACHERS, Earl J. McGrath, 24 pp., $1.00, Bureau of Publications, Teachers College, Columbia University, New York, 1961.

This is another monograph to support the author's previously stated thesis that the usual Ph.D. program does not train suitable college teachers of undergraduates. The point is based on a survey of college presidents on this issue. It is pointed out that administrators of Catholic institutions are not as firm on this point, and some reasons are given for this point of view. The implications of these opinions are given space in the discussion.

P. K.

ATTITUDES OF LIBERAL ARTS FACULTY MEMBERS TOWARD LIBERAL AND PROFESSIONAL EDUCATION, Paul L. Dressel, Margaret F. Lorimer, 55 pp., $1.75, Institute of Higher Education, Bureau of Publications, Teachers College, Columbia University, New York, 1960.

This is a survey the scope of which the title indicates. The data was collected by questionnaires to a wide variety of faculty member types. The results are what one expect: a clear-cut endorsement of a liberal education. The only quarrel seems to be in quantity and quality. It seemed to be the science faculty which insisted greatest on the most latitude in this matter, on a greater dependence on high schools to furnish breadth in education, and on a higher quality in the so-called liberal arts courses. The only trouble is that there seemed to be no clear-cut definition of liberal arts on anyone's part. One wonders when the sciences became divorced from liberal arts in the minds of many people.

P.K.

PROFESSIONAL MANPOWER AND EDUCATION IN COMMUNIST CHINA, Leo A. Orleans, 260 pp., $2.00, National Science Foundation, Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., 1960.

Some interesting statistics and conclusions are found in this book concerning the science training program and the educational system of Communist China. The author explicitly tells how difficult it was to gather reliable data on these

points. Figures from one source do not add up to the totals in the same source, for example. To the biologist, the striking information concerns exams in the biological subjects, the retention of Michurinism and other Soviet dogma. The amount of class time spent in biology is considerably lower than that of the physical sciences. Indeed, biology is not getting a proportionate share of the increased attention to education as the physical sciences. Indeed, a very interesting book which makes it quite appropriate to thank the NSF for its authorization and publication.

P. K.

LETTERS TO MY TEACHER, Dagobert D. Runes, 105 pp., $2.75, Philosophical Library, Inc., New York, 1961.

If I were the teacher to whom these letters were addressed, I would be alarmed and a little hurt at the pot-shots which are taken at education on all levels and in all places. The author uses the style of letters to deliver short polemics against special attention to the gifted child, grading systems, current attention to science education, emphasis on spectator sports, foreign language instruction, and most other things that the "average child" might have trouble with. The chief theme of this philosopher seems to be that education should be fitted for the average child, ignore evaluation schemes, and emphasize a love of truth and love for fellow mankind. Interesting book.

P. K.

SOVIET EDUCATION PROGRAMS, W. K. Medlin, C. B. Lindquist, and M. L. Schmitt. xvii + 281 pp., $1.25. U. S. Department Health, Education, and Welfare, Bulletin 1960, No. 17. U. S. Government Printing Office, Washington, 1960.

This is a report on a study made early in the summer of 1959 of the teaching methods, general facilities, and student performances in the Soviet school system. Visits were made to elementary-secondary schools, polytechnical institutions, and teacher's colleges of various sizes in different cultural regions.

Soviet educators do not believe in science survey or general science courses. Instead, they feel that the pupil must learn the fundamentals of every field of knowledge. Biology is taught in grades five through nine, and physics, chemistry, and mathematics in grades seven through ten. The report gives typical outlines of each course in biological science. Grades five and six are devoted to plant sci-

ence, grade seven to zoology, grade eight to human anatomy and physiology, and grade nine to "Principles of Darwinism." In addition to class and laboratory work, practical first hand knowledge of growing plants and animals is provided when possible. The pupils grow vegetables in garden plots and raise rabbits. In rural areas there is practical study of livestock raising.

At a time when Americans are examining their own educational programs and comparing them with those of the U.S.S.R., this report provides some interesting data.

John M. Hamilton
Park College, Parkville, Missouri

General

PLAYING WITH WORDS, Joseph T. Shipley, 186 pp., $3.50, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1961.

It may be surprising to find this book reviewed in these pages for this is a book on the games one can play by using words. Quite a variety of such games are described. But teachers will find uses for these games in teaching, especially these games. The familiar crossword puzzle used by many biology teachers will find quite a few variations in this book. A fine book with a variety of uses.

P. K.

WOODWORKING FOR EVERYBODY, John G. Shea, 219 pp., $6.50, D. Van Nostrand Company, Inc., New York, 1961.

This third edition of a successful book has been brought up to date by the incorporation of descriptions of many new materials, tools, and woodworking machines. The ten chapters include clear and comprehensive discussions of such topics as the nature and uses of wood, modern shop tools and machines, the performance of numerous specific processes, accident prevention and first aid, and the care and conditioning of tools. There is a long list of things to make with detailed directions for making them. The working directions are unusually clear and direct, and the illustrations are informative and of excellent quality.

The chapter on wood can be made the basis of a supplementary project in biology, and for the manual training shop the book will be a must. The serious adult do-it-yourself worker will find it equally valuable.

Paul Weatherwax,
Department of Botany
Indiana University